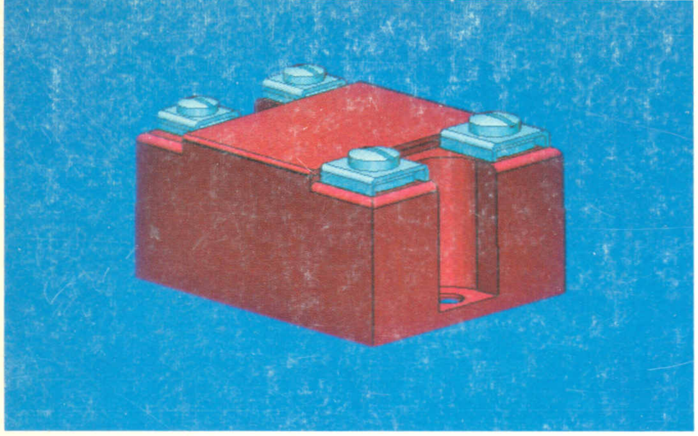
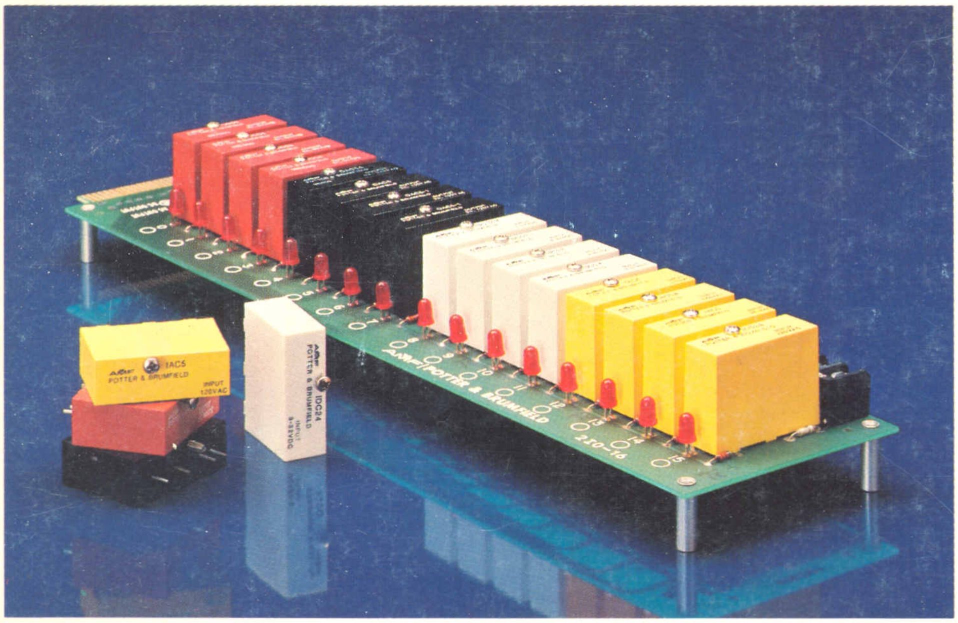
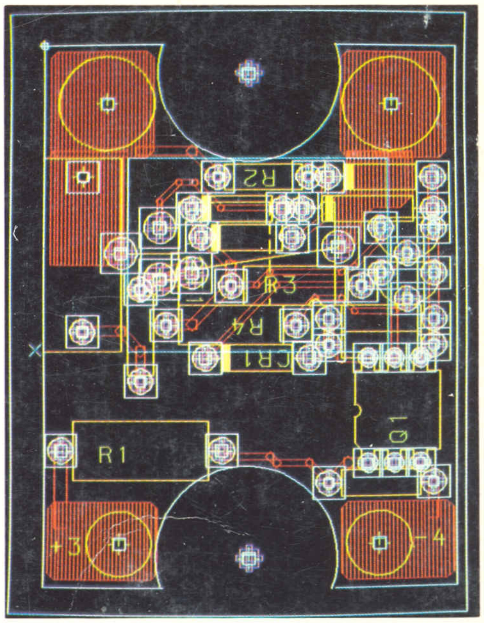
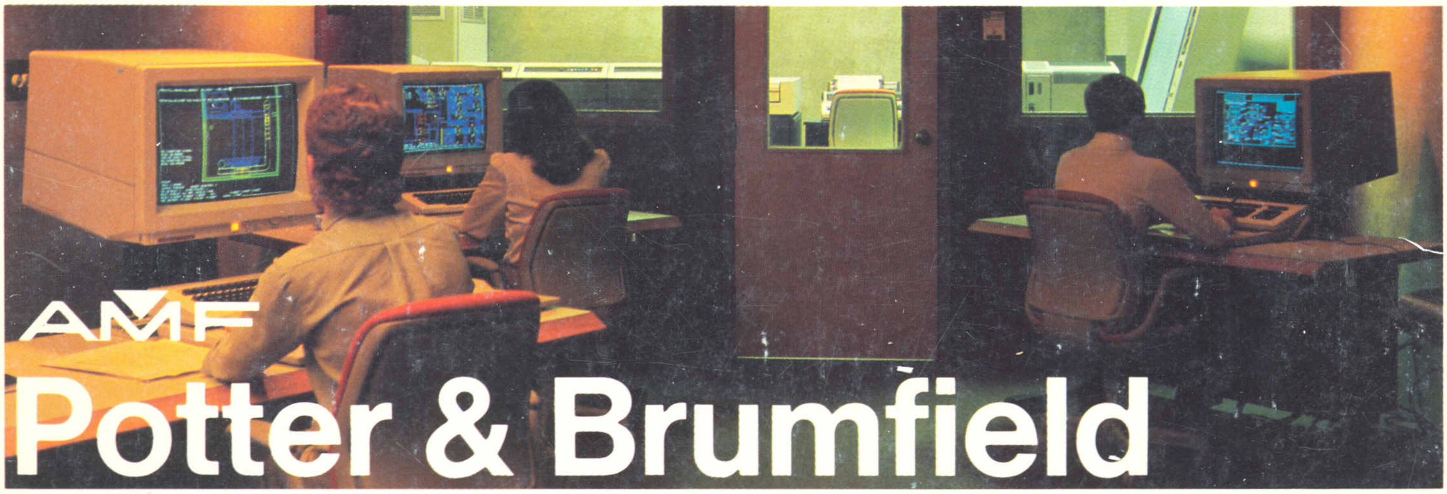








AMF

Potter & Brumfield

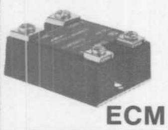
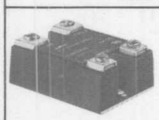
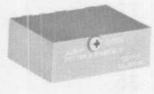
Solid State Switching Technical Data Library

Published 1984

Solid State Switching Technical Data Library

INDEX

Solid State Relay and I/O Module

Series	Optically Coupled	Reed Coupled	Zero Switching	Random Switching	LOAD Min. Current (Amps.)	LOAD Max. Current (Amps.)	LOAD Min. Voltage (Volts)	LOAD Max. Voltage (Volts)	LOAD Type	INPUT AC	INPUT DC
Solid State Relays											
 ECM		X		X	.075	40	24	280	AC		X
 ECT		X		X	.075	40	24	280	AC	X	X
 EOM	X		X		.020	25	24	280	AC		X
 EOT	X		X		.075	40	24	280	AC		X
 ETC	X		X		.050	25	24	140	AC		X
I/O Modules											
 IAC	X			X	.0001	.10	0.4	30	DC	X	X
 OAC	X		X		.020	3	24	280	AC		X
 IDC	X			X	.0001	.10	0.4	30	DC		X
 ODC	X			X	.020	3	10	60	DC		X

Input/output quad modules are scheduled to be available from Potter & Brumfield in the second quarter of 1984. Please contact your Potter & Brumfield sales representative for specifications on these units.

SELECTOR GUIDE

High Transient Noise Immunity	High Inrush Capability	Internal dv/dt Snubber	Logic Compatible	Series Operation Compatible	TERMINATION: Screw	TERMINATION: Quick Connect	TERMINATION: PC Board	APPROVALS: UL	APPROVALS: CSA	Comments	Page Reference
X	X	X	X		X			X		Hybrid Relay	23
X	X	X	X			X		X	X	Hybrid Relay	27
X	X	X	X		X			X	X	General Purpose	31
X	X	X	X			X		X	X	General Purpose	35
X	X	X	X		X					Traffic Light SSR; Meets NEMA, CA & NY Standards	39
X			X	X			X	X	X	AC Input Module	43
X	X	X	X	X			X	X	X	AC Output Module	44
X			X	X			X	X	X	DC Input Module	45
X			X	X			X	X	X	DC Output Module	46

Solid State Relay and I/O Module User's Information

RELAY TYPES AND CHARACTERISTICS

Solid state relays (SSRs) and output modules are similar to electromechanical relays conceptually in that both types employ a circuit for control and a separate circuit for load switching **(Figure 1)**. In an electromechanical relay (EMR), the coil represents the control or coupler circuit, and a movable set of contacts represents the load switch.

The load switch used in DC solid state relays and DC output modules is a transistor. In AC relays and AC output modules, it is either inverse-parallel connected silicon controlled rectifiers (SCRs) or a triode AC switch (triac).

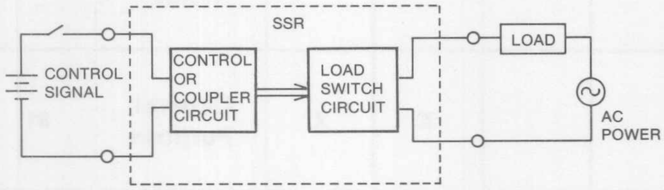


Figure 1
Functional diagram of solid state relay.

The coupler circuit controls the operation of the load switch and isolates it from the circuit controlling the relay. The coupler circuit gives the relay the versatility to accept a variety of input voltages and currents, either AC or DC, regardless of load voltage and power. The coupler, in effect, characterizes the relay.

Three types of couplers are most commonly used. Hybrid SSRs generally utilize a reed relay coupler. Opto-coupled SSRS use a light-emitting diode (LED) and a photo detector. The third type of coupling consists of a small transformer and associated circuitry.

Reed-Relay Coupled Hybrid Solid State Relays (HSSR)

A hybrid solid state relay is typically a one form A (SPST-NO) four terminal device. Input-to-output isolation is provided by a reed relay.

A reed relay consists of a reed switch around which a coil is wound. When rated voltage is applied to the coil, the resultant magnetic field closes the reed blades **(Figure 2)**.

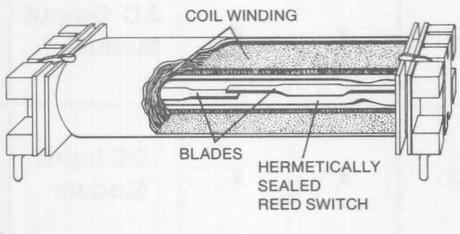


Figure 2
A reed relay consists of a reed switch in a capsule around which a coil is wound.

Potter & Brumfield uses a unique reed for HSSR use. The testing, contact signature, pick-up and drop-out differential, plating, internal pressure and atmosphere, plus blade configuration, are closely controlled for maximum performance in HSSRs. These reed capsules will typically perform dependably for tens of millions of operations. Care should be taken, however, to operate the reed input within specified limits.

The input (reed coil) normally requires more power (300 to 450 mW) than the other types of SSRs (30 to 100 mW). Potter & Brumfield's experience indicates that 300 mW is needed for the reed relay controlling a triac switching 120V, 50/60 Hz. Generally, 450 mW is desired for controlling a triac that switches 240V, 50/60 Hz.

The operate time of the reed relay is typically 0.6 ms. This is not a deterrent in most applications where line voltage frequency is 50 or 60 Hz.

In rare applications the reed relay coupler operation may be affected by stray magnetic fields. This condition is easily remedied by magnetic shielding.

Mechanical shock is not usually a problem unless forces in the order of 100g's are encountered. Vibration should not be of concern unless forces in the order of 20g's in the frequency range of 2,500 Hz are present. Input-output isolation of the reed coupler is $>10^9$ ohms, and breakdown voltage is $>1{,}500$ rms, 60 Hz (designs can be provided to exceed 3,750V rms, 60 Hz).

Potter & Brumfield HSSRs are random turn-on devices. Zero voltage turn-on is possible but there are a considerable number of components required to accomplish this, and cost usually is prohibitive.

Although the random turn-on causes some EMI and RFI, the amount may be up to 50 times less than that produced by the making of hard contacts of an EMR due to the multiple openings and closings (bounce) of EMR contacts. Also, it is the nature of the HSSR load switch to turn off only when load current is near zero. Therefore, there is no EMI as a result of a rapidly collapsing magnetic field of the load circuit.

Due to the inherent nature of their basic design, HSSRs **(Figure 3)** are simpler, cost less, have fewer components, and have inherently greater overall transient immunity than SSRs.

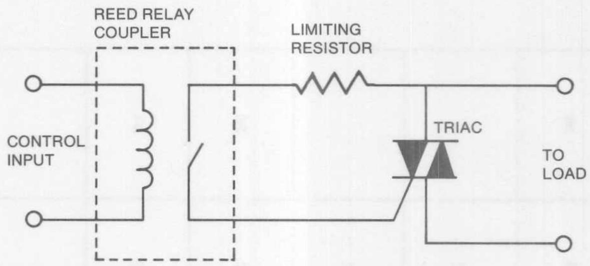


Figure 3
Functional diagram of reed coupled SSR.

Optically Coupled Solid State Relays

An optically coupled solid state relay is typically a one form A (SPST-NO) four-terminal device. Isolation is provided by optical means between the control (input) terminals and the load switch **(Figure 4)**. The opto-coupler accepts relay control voltage and, via the LED, converts this power to light energy. This light is collected by a photo detector which controls the thyristor gate-firing circuit or zero voltage detection circuit. Input-output isolation is 10^9 ohms, and breakdown voltage is 1,500V rms, 50/60 Hz, with 2500V rms and 4000V rms optional. The characteristics of the LED permit control circuit designs that accept a wide range of input voltages.

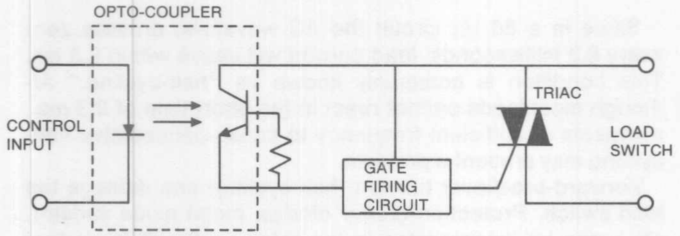


Figure 4
Functional diagram of opto-coupled SSR.

Based on a 10% reduction in light output, the life expectancy of an opto-coupler is in excess of 50,000 hours. The opto-coupler is actuated in microseconds, is not normally affected by shock or vibration, has no bounce, and can be driven directly by many MOS and TTL gates.

The on/off state of the photodetector controls the state of the logic that permits gating of the output triac. Optically coupled designs usually feature zero voltage turn-on of the triac (see page 11). That is, if input control voltage is applied when instantaneous load-line voltage is greater than approximately 20 volts, the triac remains off until line voltage crosses zero and increases to the turn-on voltage of the triac circuitry—typically just 3 or 4 volts. This reduces EMI at turn-on to less than one-hundredth that of an EMR, and approximately one-fifth that of an SSR without zero voltage turn-on.

After initial turn-on, successive half cycle turn-on for SSRs requires 5-10V across the triac, depending on the load being switched. Generally, 5-15 mA is required to properly operate the coupler. Currents in excess of 20-25 mA may start deterioration of the LED coupler, particularly at elevated temperatures.

Fixed input SSRs are available to operate from supplies of 5, 6, 12 and 24 VDC. Also offered is a universal input type that operates from 3-32 VDC. Potter & Brumfield's experience is that the fixed input types are more performance/cost effective.

Care should be exercised to match the following input characteristics to the input of the actual application:

1. Must operate voltage and current.
2. Must *not* operate voltage and current.
3. Maximum permitted voltage, and maximum reverse voltage.

The theoretical advantages of the SSR over the HSSR may not always be realized in practice due to the SSR's greater number of component parts, several of which must withstand the voltage stresses encountered by the output switch.

Transformer Coupled Solid State Relays

A transformer coupled SSR is typically a four terminal device available in SPST-NO (one form A) configuration. Relay control voltage operates an oscillator, the output of which provides primary current in a toroidal transformer. Oscillator frequency ranges from 50 kHz to 500 kHz. The transformer output controls the thyristor gate-firing circuit **(Figure 5).**

Input-output isolation is $>10^9$ ohms, and breakdown voltage is $>$1,500V rms, 60 Hz. Unlike an opto-coupler, the performance of a transformer coupler does not degrade noticeable over the life of the relay. In addition, the transformer coupled SSR has fewer total components than the opto-isolated SSR, and is less temperature sensitive. However, it does not have the zero voltage turn-on feature.

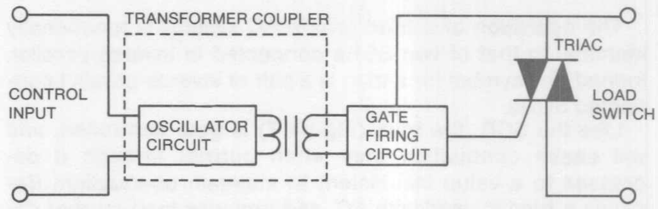


Figure 5
Functional diagram of transformer-coupled SSR.

THE LOAD SWITCH

To properly apply solid state and hybrid relays, it is necessary to have a fundamental working knowledge of the operation of these relays. Since a great many operational considerations in AC systems involve the load switch, the load switch will be examined in detail.

A silicon controlled rectifier (SCR) is a four-layer semiconductor device having three terminals: cathode, anode, and gate **(Figure 6)**. It normally blocks current in both the forward and reverse directions. It may be triggered on in the forward direction by the injection of a small current into its gate. Once on, the SCR remains on until load current decreases to a value less than that necessary to maintain conduction. For switching AC loads, two SCRs are connected in inverse-parallel, or a triac is used.

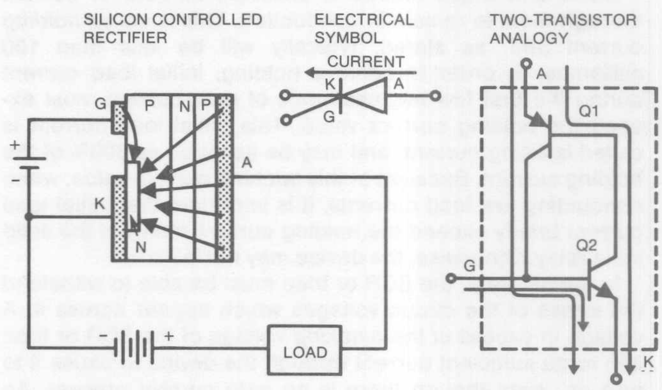


Figure 6.
Functional diagram of SCR.

The operation of an SCR can best be understood by a two-transistor analogy. As shown in Figure 6, the base of one of the transistors is actually the gate of the SCR. The open emitter of the NPN is the cathode of the SCR; and the open emitter of the PNP is the anode of the SCR.

Assuming a complete (load) circuit, when base current is injected into Q2, its collector pulls current through the base-emitter junction of Q1. This current causes Q1 collector current; the base-emitter junction of Q2 being the source path for Q1 collector current. Q2 goes into saturation, as does Q1. Gate current can now be discontinued, but because each transistor holds the other in saturation, the SCR will continue to conduct. The SCR will cease conduction only when current through it decreases to a value insufficient to maintain that conduction—typically less than 100 milliamps. While in conduction, the voltage drop of the device approximates the drop of a single PN junction. That is, the drop may be just a fraction of a volt to perhaps 1 or 2 volts, depending on load current.

The operation of a triac (*trio*de *AC* switch) is functionally identical to that of two SCRs connected in inverse-parallel. Indeed, the symbol for a triac is a pair of inverse-parallel connected SCRs.

Like the SCR, the triac **(Figure 7)** is gate controlled, and will cease conduction only when current through it decreases to a value insufficient to maintain conduction. Because a triac is used with AC, and because load current decreases to zero every half cycle, the triac ceases conduction twice each cycle. However, as long as gate current is present, the triac will immediately resume conduction after load voltage crosses zero and begins to increase in magnitude.

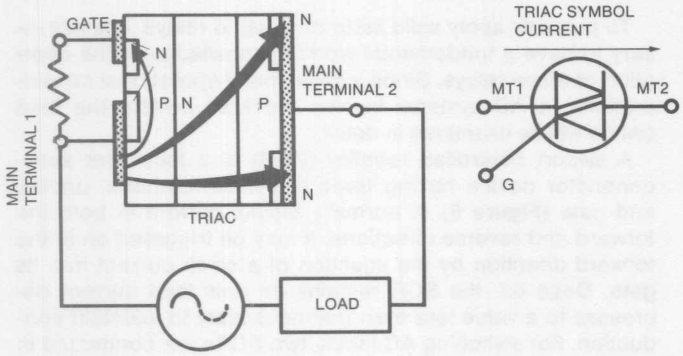


Figure 7
Functional diagram of triac.

SCRs and triacs require a minimum amount of current through them to remain in conduction. This is called *holding* current and, as stated, typically will be less than 100 milliamps. In order to achieve holding, initial load current during the first few microseconds of gate current must exceed the holding current value. This initial load current is called *latching* current, and may be as much as 300% of the holding current. Because of this latching current value, when conducting low load currents, it is important that initial load current briefly exceed the holding current rating of the solid state relay. Otherwise, the device may not latch on.

In the off-state, the SCR or triac must be able to withstand the stress of the circuit voltages which appear across it. A voltage in excess of the *blocking* voltage of the SCR or triac can force sufficient current through the device to cause it to turn on, even though there is no gate current present. An overvoltage of just a few microseconds in duration can result in unwanted turn on. Once on, of course, the device will remain on until load current decreases to less than the holding current value.

Every SCR and triac has a rated blocking voltage, sometimes called *withstand* voltage. This blocking voltage is rated for given temperature limits. Exceeding the temperature limit will decrease the blocking voltage rating. That is, the device will not be able to withstand the value of voltage for which it is rated. A brief but excessive overcurrent, for example, can cause a momentary increase in junction temperature sufficient to lower the blocking value of the device. Should the device immediately be turned off by removal of gate current, any overvoltage (or even line voltage peaks) may cause it to turn right back on. This condition will exist until junction temperature returns to within its rated specifications.

In many applications the relay load circuit is in parallel with other circuits. The operation of these circuits (when controlling inductive loads) often impose spurious voltages on the AC line. These transients may have an amplitude in excess of the forward-breakover voltage of the SCR or triac and a time duration sufficient to cause the device to turn on. If so, the relay will remain on until load current decreases to below the holding current value.

Since in a 60 Hz circuit the AC waveform crosses zero every 8.3 milliseconds, load current will cease within 8.3 ms. This condition is commonly known as "half-cycling." Although most loads cannot react in the short time of 8.3 ms., transients of sufficient frequency to cause consecutive half-cycling may present a problem.

Forward-breakover turn-on (half cycling) can damage the load switch. Protection (zener diodes, metal oxide varistor, etc.) may be incorporated in the relay or circuit to protect against such overvoltage false triggering.

There are two blocking voltage ratings for an SSR, *repetitive* and *nonrepetitive.* Both are usually found in the data sheet. Generally, the repetitive peaks of the AC line voltage should not exceed 90% of the repetitive blocking voltage rating for the relay. Potter & Brumfield's 120V AC SSRs have a ±200V minimum rating, and 240V AC units have a ±400V minimum rating.

In applications where the relay is off for long periods of time, continual blocking of normal load voltage may cause more stress on the relay than switching or conducting steady state load current. In such cases, for maximum relay life, a repetitive blocking voltage rating of 1.5 to two times the peak of the rms load voltage should be considered.

In addition to imposing voltage transients on the line, parallel loads can impress overvoltages on the SSR. For example, upon being turned off, a motor becomes a generator and may cause an AC voltage in excess of the normal line voltage to appear across the relay. Such a voltage should be within the repetitive blocking rating of the relay. To ensure proper relay selection, always measure complete application and load conditions.

Turning off highly inductive loads near zero current can generate induced voltage transients up to twice the peak of the applied rms load voltage. (The presence of the snubber capacitor limits the induced voltage to approximately twice line voltage.) Such nonrecurring transients must not exceed the nonrepetitive blocking rating for the relay. Otherwise the relay may turn right back on, resulting in an uncontrolled-on load.

A typical minimum rating for nonrepetitive blocking voltage of P&B SSRs is ±300V for 120V AC units, and ±600V for 240V AC units.

It is thus obvious that in the selection of an SSR, a relay whose blocking rating is greater than the worst-case conditions of the load circuit should be specified.

dv/dt False Operation

SCRs and triacs possess the unique ability to be turned on from a steeply rising voltage impressed across them. Transistors, on the other hand, are not as sensitive to this type of false operation.

Rate of rise is designated by the Greek delta (Δ), abbreviated simply by the letter *d*. Delta is given for either current (*i*) or voltage (*v*) with respect to time (*t*), which typically is 1μ sec. Thus, the rate of rise (change) of voltage is designated dv/dt.

Every semiconductor junction possesses inherent capacitance. Because of this capacitance, a rapidly rising voltage will cause a capacitive current through the junction at the rate of $i = C\ dv/dt$. If this current is in excess of that required for latching, the SCR or triac will latch on. Once on, it will remain on until current decreases to less than the holding current value. Such rapidly changing voltages are known as static and commutating dv/dt.

It is not the magnitude of voltage that causes the switch to false operate. Indeed, the voltage peak may be well within the blocking capability of the switch. But if the dv/dt is perhaps nearly vertical—that is, a step function—the switch may turn on.

Static dv/dt is present in many load circuits as a result of motors, solenoids, switches and other devices being operated in the same branch circuit; commutating dv/dt is the result of the SSR or output module turning off an inductive load. *Commutating dv/vt* identifies the rate of rise of line voltage appearing across a switch upon turning off an inductive load.

As shown in **Figure 8,** while the load switch is in conduction, voltage across the switch (E_{triac}) is minimal. When relay or module control voltage is removed, Point A, the switch ceases conduction at the next zero current point (Point B). Because inductive voltage and current are out of phase, when current ceases, voltage across the switch tries to increase instantly to line voltage. The dv/dt of this voltage may be sufficient to cause the switch to resume conduction, even though there is no control voltage present. Under this condition, the load can only be turned off by opening the circuit at some other point.

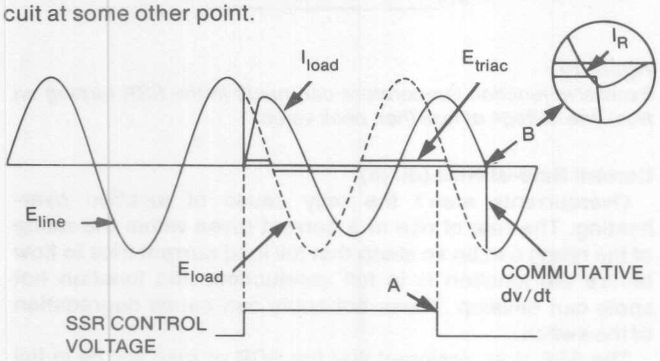


Figure 8
Commutating dv/dt occurs as a result of switching off an inductive load.

Typically, SSR manufacturers rate commutating dv/dt for a given power factor. For example, if the relay has a steady state rms current rating of 10 amps, .40 P.F. load, it should be able to turn off any load of 10 amps or less having a power factor of .40 to 1.00. If power factor is less than .40 (i.e., more inductive), the relay may not turn off when input control is removed and the load current falls below the minimum holding current of the relay. Thus, it is important to identify the power factor of the load *circuit* before selecting the relay to switch that circuit.

To protect the SCR or triac from the step function of steeply rising voltages, a series resistor-capacitor dv/dt network, sometimes called a *snubber* network, is connected in parallel with the switch **(Figure 9).** This snubber network is an integral part of many SSRs and output modules. When the SCR or triac is off (static) and when it is just turning off (commutating), as voltage begins to appear across both switch and snubber, the capacitor begins to charge, the rate of charge being limited by the snubber resistor. The result is that voltage does not appear across the switch as fast as it would without the snubber circuit, and the switch is less likely to false operate.

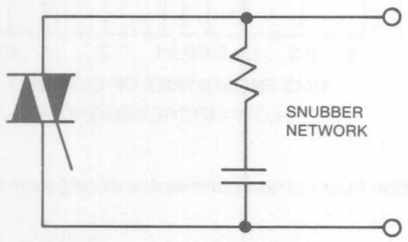


Figure 9
A snubber network helps prevent dv/dt false operation.

The static and commutating dv/dt ratings of any given SSR or module will be different. This is because of junction heat and load current. Under static dv/dt conditions, the switch is off and the junction is cool. However, when commutating dv/dt occurs, the junction is warm and unable to withstand as steep a rate of change of voltage. It is the nature of the SCR and triac that the higher the current being conducted, the lower the dv/dt capability of the SCR or triac. Since the SSR user cannot alter load current, it becomes necessary to keep the SSR as cool as possible.

The dv/dt rating of a solid state relay or output module is a function not only of the switch and snubber capacitor, but also of the value of snubber resistance. This resistance is necessary to prevent the capacitor from dumping its charge onto the switch. Without the resistor, the capacitor would discharge instantly, perhaps causing the switch to false operate.

Depending on make and model of SSR or module, the snubber resistor may be any value from less than 30 ohms to more than 100 ohms. Of course, the lower the resistance, the faster the capacitor will charge and the higher the dv/dt rating of the switch. Naturally, a switch that has a dv/dt rating of 500 V/μsec. is far more immune to dv/dt false operation than a switch that has a rating of 100V/μsec.

Another way of looking at the need for a small value of snubber resistance is voltage division. Since any transient voltage will divide between the resistance of the load and the snubber resistance, the higher the snubber resistance, the greater the possibility of a step-function voltage appearing across the switch.

The snubber resistor is needed for yet another reason. It controls capacitor discharge should the switch be turned on at or near peak line voltage and of such polarity that capacitor discharge adds to line voltage. Under this condition, and without the resistor, capacitor discharge current would add to load surge current. The resultant total surge current might damage the switch.

Usually, the SSR or module manufacturer will select the snubber resistor based on the surge current rating of the switch. Those manufacturers who use a switch with a high surge current rating can use a low value of resistance. Those manufacturers who use a switch with a low surge rating must use a higher value of snubber resistance.

Thermal Turn-On

Thermal turn-on can result when the SSR is placed in a high ambient temperature that raises the off-state junction temperature above the limit of the SCR or triac. At high temperature, leakage current doubles approximately with every 8°C increase in junction temperature. When leakage current causes the loop gain of the SCR or triac to approach unity, the switch goes on. Only a gross misapplication would allow this situation to occur, however.

Should thermal turn-on occur, input control is lost. To turn off the load, the load circuit has to be broken at another location. After a thermal turn-on, the additional heat due to load current I^2R loss can contribute to thermal run-away and destruction of the load switch. For these and other reasons outlined in this guide, it is important to operate the SSR within its maximum temperature rating.

Current Ratings

Excessive heat frequently is a contributing factor in early failure of the SCR or triac. That is, excessive heat can cause degradation of the crystalline structure of the device, and can result in a rupture of the structure. Therefore, every effort should be taken to keep the operating temperature of the SSR load switch as low as possible.

Heat is generated at a rate of .057 btu per watt per minute. (One btu is the amount of heat required to increase the temperature of one pound of water 1°F.) The more power the SCR or triac consumes, the greater the temperature of the device. Since $P = I^2R$, it is obvious that heat is directly related to current. Because of this fact, SSRs have three maximum current ratings which must be observed if maximum life is to be realized from the relay. These maximum ratings are: steady state rms current; peak, nonrepetitive, one cycle surge current; and peak repetitive (or recurrent) surge current. They are based on a maximum allowable SCR or triac junction temperature of +100°C to +125°C. Exceeding any of these ratings, even briefly, can result in degradation of the SCR or triac. Such degradation is permanent and, in time, when the device repeatedly subjected to such overcurrents, the cumulative effects will cause device failure.

The *steady state current* rating denotes the maximum amount of continuous rms load current the relay can safely conduct without overheating. The *peak, nonrepetitive, one cycle surge current* rating (I_{TSM}) denotes the maximum permissible peak current of one 50 or 60 Hertz cycle. Typically, the I_{TSM} is 10 times the steady state current rating. The *peak repetitive surge current* rating denotes the maximum amount of repetitive current peaks the relay can safely conduct.

Since heating is a function of time, relay overcurrent ratings are given with respect to time. Repetitive surge current is usually given for 100 milliseconds, and non-repetitive surge current is usually given for the peaks of one full cycle of current. Of course, for 60 Hz. current, the time duration of one cycle is 16.6 milliseconds.

Even though load surge currents may be within the listed maximum ratings of the relay, junction overheating may still occur. Should input control be removed from the SSR immediately following a surge current, the blocking capability of the SCR or triac load switch may become temporarily less than line voltage peaks. If this happens, the load switch will turn on when line voltage increases to greater than the lowered blocking capability of the switch.

For example, when the SCR or triac junction temperature is less than its maximum rating, the blocking capability of the switch may be, say, 200 volts. Thus, the peaks of 120V rms (i.e., 170V) will not cause the switch to turn on.

However, excessive temperature causes thermal agitation of both majority and minority charge carriers within the semiconductor. Because of this increased movement of the charge carriers, less voltage is required to cause breakover (turn on) and conduction. Under this condition, perhaps just 150 volts or less will cause breakover and conduction.

As shown in **Figure 10,** assume input voltage is removed from the SSR when instantaneous load voltage is at Point A. The SCR or triac ceases conduction at Point B, and should remain off. However, when line voltage increases to 150 volts (Point C), breakover occurs. Load current flows until Point D, then ceases until Point E, and so on until junction temperature returns to within specifications. Because of this uncontrolled-on condition, gate control is said to be lost.

The repetitive surge current rating of the SSR typically is low enough that rated surges have no deleterious effect on the life of the relay. Nonrepetitive ratings, conversely, are usually a measure of the amount of peak current which may result in minimal but *cumulative degradation* of the SCR or triac. Because of this, the nonrepetitive rating is given for a maximum number of such peak surges. At some time after the listed number of such peak surges have been attained, the SSR may be expected to fail. To prevent subjecting the relay to destructive peak surges, the relay user should select an SSR whose maximum ratings are well in excess of the worst case application condition expected.

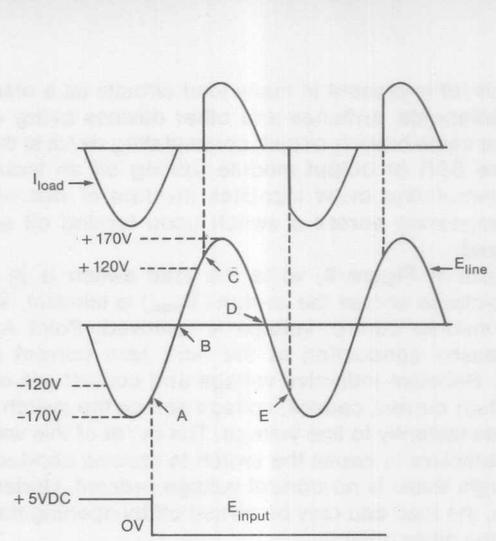


Figure 10
Excessive junction temperature can result in the SSR turning on from line voltage of less than peak value.

Current Rate-of-Rise (di/dt)

Overcurrents aren't the only cause of junction overheating. The rate of rise of a current (even within the rating of the relay) can be so steep that full load current tries to flow before the junction is in full conduction, and junction hot spots can develop. These hot spots can cause degradation of the switch.

The SSR is so designed that the SCR or triac will be in full conduction typically between 1 and 10μsec. after application of gate current. During this turn-on period, the rate of rise of load current must be slow enough that at any given instant the device is not subjected to more current than it can safely conduct.

As shown by **Figure 11,** a particular SCR might be able to safely handle 50 amps one microsecond after load current begins, as denoted by Point A. At 0.2μsec. after load current begins (Point B), load current must not exceed 10 amps. At 0.4μsec., current must not exceed 20 amps, and so on.

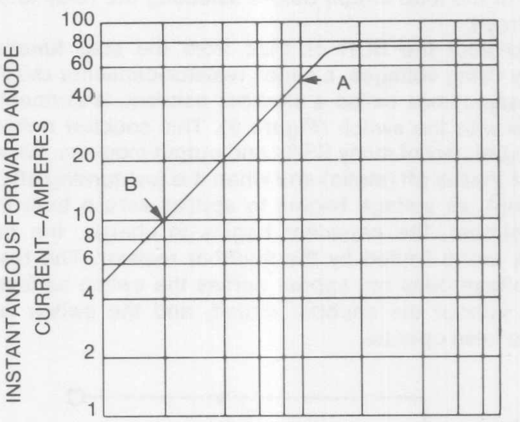


Figure 11
Initial SCR/triac load current permissible during turn-on.

Load current di/dt is determined by the load circuit, not merely by the load itself. The circuit of a primarily resistive load, for example, may contain such a length of conductors that a considerable capacitance is present. When power is initially applied to the circuit, at time zero there is an instantaneous inrush of current limited only by circuit resistances. Such an inrush may have a di/dt of hundreds of amps per microsecond. If such is the case, an inductance may be placed in series with the load to limit di/dt. The inductive reactance causes a lag in current, and compensates for the lead caused by the capacitance. A highly inductive circuit, of course, retards di/dt the most. It is for this reason that some SSR users include a saturable reactance in their circuit, if stray inductance isn't sufficient to limit di/dt to an acceptable amount.

Load current di/dt during normal input controlled turn on should not exceed 50 A/μsec., whereas di/dt for a voltage breakover condition should not exceed 10 A/μsec. It must be noted, however, that the SSR should never be subjected to voltages in excess of its blocking voltage rating. Doing so will result in an unwanted operation of the load. When determining the di/dt of an application, current discharged through the SSR load switch by any external snubber capacitor used must be taken into consideration. Although limited by the snubber resistor, this current adds to the rate of rise of load circuit current.

Heatsinking

As stated, unless junction heat is dissipated, maximum allowable junction temperature will be exceeded and structure degradation may result. At the very least, normal electrical characteristics of the device may be temporarily altered.

To aid in heat dissipation, a thermally conductive path is provided between the load switch and the air surrounding the relay. This path is provided both by the potting compound in which the relay is encapsulated, and by the relay baseplate.

The potting compound is a liquid plastic containing a large concentration of a thermally conductive material such as silica or alumina. Once poured into the relay, the plastic solidifies. Heat from the load switch travels through the compound and is radiated by the relay case into the surrounding air.

The thermal path to the relay baseplate is provided by a beryllium oxide disc **(Figure 12)** which separates the load switch from the baseplate. Ideally, the switch would be soldered directly to the baseplate and the baseplate would pull heat out of the switch. Since the case of many SCRs and triacs, however, is electrically "hot", electrical isolation between switch and baseplate is necessary. The beryllium oxide disc provides this electrical isolation, yet provides an excellent thermal path. The load switch is soldered to the disc and the disc is soldered to the baseplate. If desired the baseplate may be mounted to a heatsink. Heatsinks, of course, enable the SSR to switch larger current.

The rating for heatsinks is given in thermal resistance (°C/W). Thermal resistance is the ratio of the temperature rise of the heatsink to the rate in watts at which heat is generated. A heatsink rated 1°C/W is thermally more efficient than one rated 3°C/W. That is, the 1°C/W heatsink will dissipate more heat than the 3°C/W heatsink. For a 30 watt heat source, the temperature of the 1°C/W heatsink will increase only by 30°C, while the temperature of the 3°C/W heatsink will increase by 90°C. Add these temperature rises to normal ambient temperature of, say, +25°C, to obtain total heatsink temperature.

Since the SSR load switch is the heat source, it will always be hotter than the heatsink. This means the 3°C/W heatsink cannot be used with an SSR that is generating 30 watts simply because the sink would not pull enough heat from the relay and the junction temperature of the switch would exceed the maximum allowable of +100°C. The efficiency of such a heatsink can be increased, however, simply by placing it in a forced stream of air, or by mounting the sink to a refrigerated surface.

The steady state current rating of chassis mount SSRs is listed for the relays with and without a heatsink. The reason for this is that by use of a heatsink, a given relay can safely conduct more current than it can without a heatsink.

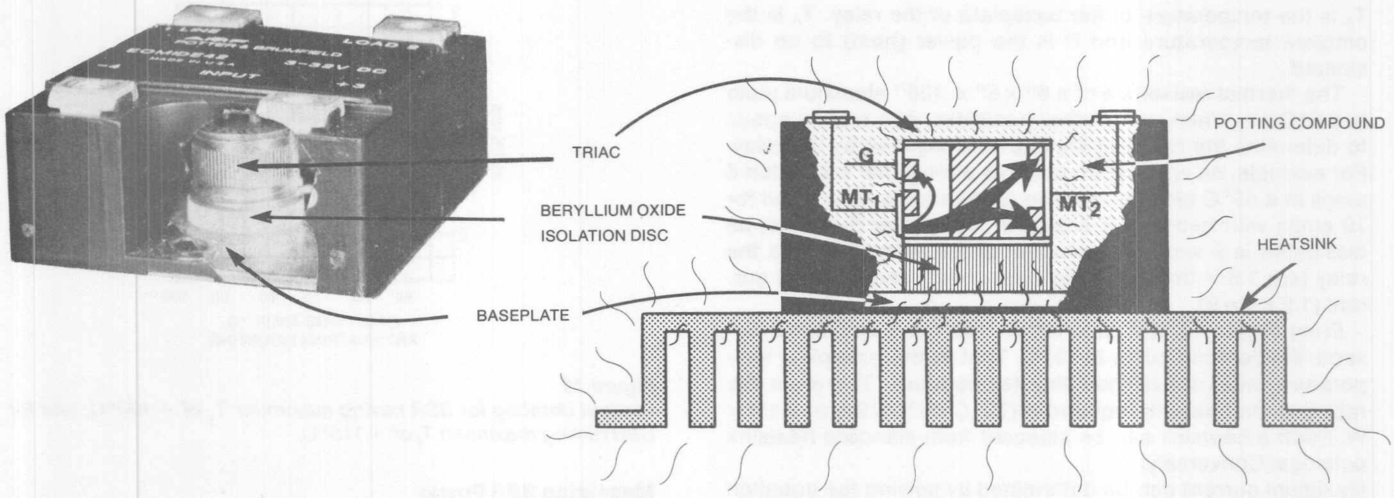


Figure 12
SCR/triac load switch heat is dissipated via both the beryllium-oxide disc and heatsink, and by the potting compound through the case to the surrounding air.

As shown by the derating curve for free air mounting in **Figure 13,** a given SSR may be able to safely conduct only 6 amps without a heatsink. When used with a 2°C/W heatsink, that same relay will safely conduct 15 amps. Note, though, that the curve in both charts is derated from +25°C to a maximum operating temperature of +80°C ambient. This means that if the relay is in an equipment cabinet, for example, the ambient temperature of which (including the heat generated by the relay itself) is +40°C, the current handling capability of the relay must be derated to 4.5 amps without heatsink, and 11 amps with heatsink.

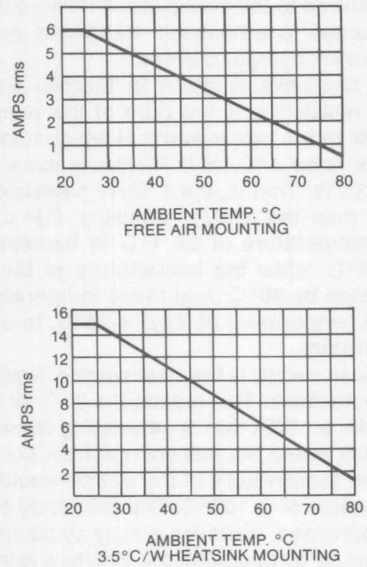


Figure 13
Solid state relay current derating curves.

The formula for the thermal resistance of the heatsink is:

$$R_{\theta B\text{-}A} = \frac{T_B\text{-}T_A}{P} \ (°C/W)$$

T_B is the temperature of the baseplate of the relay. T_A is the ambient temperature and P is the power (heat) to be dissipated.

The thermal resistance of a 6″ x 6″ x .125″ aluminum plate is 3.5°C/W. When using other heatsinks, one merely needs to determine the rating of the heatsink required by the relay. For example, an application requires a relay that will switch 6 amps in a 45°C ambient. For the application a relay rated for 10 amps with heatsink is selected. The power that must be dissipated is 9 watts, the product of the voltage across the relay (e.g. 1.5 V from the relay data sheet) and the load current (1.5 x 6 = 9).

From **Figure 14,** it is determined that the 6 amp line intersects the derating curve at 73°C. That is, the baseplate temperature must not exceed this temperature. Therefore the rating of the heatsink required is (73°C-45°C)/9W or 3.1°C/W. Such a heatsink can be selected from standard heatsink catalogs. Conversely:
Maximum current can be determined by solving the equation as follows:

$$P = \frac{T_B\text{-}T_A}{R_{\theta B\text{-}A}} \text{ and } I = \frac{P}{V}$$

And maximum ambient:

$$T_A = T_B - P_{\theta B\text{-}A}$$

Performance and reliability will be enhanced considerably by operating the relay as far below maximum temperature ratings as practical.

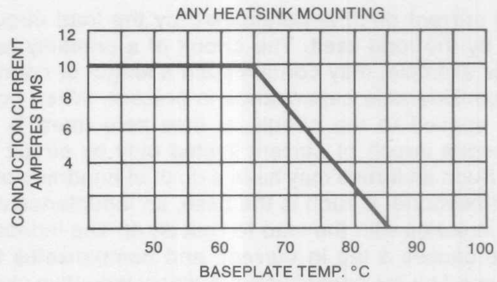


Figure 14
Current derating vs. SSR baseplate temperature.

When mounting relay to heatsink, make sure the surface of both the relay base plate and heatsink are clean and free of any oxidation. Liberally coat the baseplate and heatsink surfaces with a thermally conductive compound such as a silicone grease and torque the relay mounting screws to insure secure mounting

Ambient temperature derating curves are useful for most applications. They are plotted to insure that the SCR or triac junction temperature is maintained below the maximum allowable. A more accurate method of determining the amount of derating required is by measuring the temperature of the relay baseplate while the relay is conducting load current. Such measurement is accomplished by use of a thermocouple, and is more meaningful than simply measuring the ambient temperature.

The temperature of the operating relay is measured on the relay baseplate anywhere near the mounting screw. By locating the value of measured temperature on the appropriate derating chart, the relay can be derated accordingly. Note in **Figure 15** that for one relay, derating is to +85°C, while for another relay derating is to +100°C. The maximum junction temperature (T_j) of the first relay is +100°C, while the maximum allowable for the other relay is +115°C. Thus, the derating curves allow for a 15° differential between junction and baseplate temperatures.

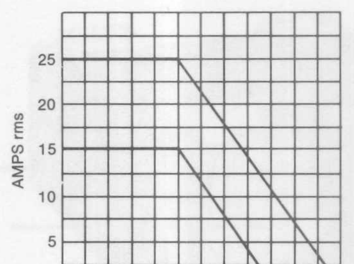


Figure 15
Current derating for SSR having maximum T_j of +100°C, and for SSR having maximum T_j of +115°C.

Measuring SSR Power

The power consumption and resultant temperature rise in the load switch are the direct result of the resistivity of that switch. By its very nature, the switch (semiconductor) has a certain on-state resistance which is detectable only by measuring the on-state voltage drop of the switch. (Do *not* use an ohmmeter to try to measure on-state resistance.) As with any resistance, the greater the current through the switch, the greater the voltage drop across it (E = IR).

This on-state voltage drop is useful in determining the amount of power being consumed by the switch, and thus arriving at an approximation of the amount of heat being generated.

That is,

$$P = EI$$

where, P = power in watts.
E = on-state voltage.
I = load current.

Of course, once power in watts is known, heat may be calculated at .057 btu/W/min.

Measurement of on-state voltage is the only way to determine whether the relay is "on" (should the load not react). Some SSR users try to check the SSR in the same manner they check the contacts of an electromechanical relay. That is, they place on ohmmeter across the switch. As stated, an SSR can only "turn on" when load current is present. If the load circuit is open or at very low current levels, the relay will not go on even though relay input voltage may be present.

Both reed and transformer coupled relays are random turn-on devices. That is, load current will begin immediately upon application of SSR control voltage. As shown in **Figure 16**, if line voltage happens to be at or near peak the instant load current begins, a steep di/dt may occur as current rushes to the maximum allowed by the circuit resistances and the value of instantaneous load voltage. Since it takes between 1 and 10 microseconds from the instant of gate current for the SCR or triac to be in full conduction, an excessively steep di/dt can cause junction overheating and possible junction degradation. Additionally, the rush of current may be detrimental to the load itself.

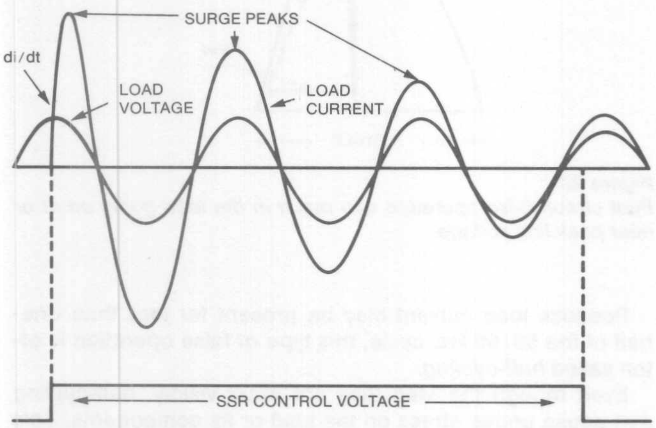


Figure 16
With random turn-on switching, the load may be turned on at or near peak line voltage. Maximum EMI/RFI results.

For example, when the filament of an incandescent lamp is cold, its resistance is but a fraction of the hot resistance. Turning on the lamp at or near peak line voltage results in maximum twisting and flexing as the filament comes up to heat. Over the life of the lamp, this sudden and repeated twisting and flexing may cause early fatigue of the filament.

There's another negative effect of random switching: the generation of electromagnetic interference (EMI). As the magnetic field surrounding a conductor builds and collapses, it gives off energy. (The principle is the same as the energy radiated from the antenna of a radio broadcast station.) In a circuit where di/dt is very steep, there is a sharp change in the magnetic field as it builds from zero to maximum, or decays from maximum to zero. This steep rate of change generates maximum EMI which may be detectable across a range of frequencies from HF to VHF. Because this energy is detectable at radio frequencies and above, it is sometimes referred to as radio frequency interference (RFI). Thus, EMI and RFI are terms often used synonymously.

EMI is generated by and all along the line of the load being switched, and may be detectable from a maximum distance of just a few centimeters from the line, to several meters. Any conductor lying within the EMI/RFI field will have a voltage induced in it as a result of the rate of change of that field cutting across the conductor. Such conductors are the load and control lines of neighboring circuits or equipment.

The voltage induced in neighboring circuits will appear across the circuit components as transient voltage. If these components are sensitive semiconductor devices, the dv/dt of the voltage may be sufficient to cause them to turn on. If not, the magnitude of the voltage may cause them to conduct. Should this occur, the overvoltage, however brief, can force an overcurrent through the device sufficient to destroy its junction. At the very least, the device may false operate.

EMI/RFI is especially troublesome when detected by low-level solid state components, microprocessors, computers, and medical diagnostic and monitoring equipment. It can cause logic gates to switch from high to low, or low to high. It can cause switching circuits to go off when they are supposed to remain on. And it can cause load switches to false operate.

EMI/RFI is greatly minimized by turning on the load only when instantaneous line voltage is near zero. Additionally, there is less di/dt and surge current to stress both junction and load.

ZERO-VOLTAGE SWITCHING

A zero voltage turn-on SSR is so designed that if SSR control voltage is applied when instantaneous load-line voltage is greater than perhaps 15 to 20 volts (**Figure 17**), the load switch will remain off until line voltage crosses zero and then increases to the turn-on voltage value of the switch. This turn-on voltage varies from unit to unit within a range of voltage, commonly called *window voltage*. From this, the term *turn-on window* was derived.

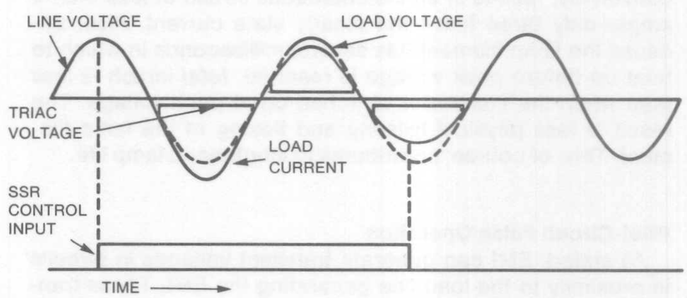


Figure 17
With zero-voltage turn-on, load current can only begin when line voltage is near zero. Minimum EMI/RFI results.

If SSR control voltage is applied when instantaneous line voltage is approaching zero, the SSR may turn on, but will go off as line voltage crosses zero. Then, as line voltage begins to increase, the SSR goes on again and remains on. It should be noted that the turn-on window of P&B zero turn-on SSRs does not exceed 20 volts, and is typically just 16 volts. The turn-on window of the SSRs and output modules of some other manufacturers, conversely, may be as high as 80 volts.

If SSR control voltage is applied to any such relay when instantaneous line voltage is 60 or 80 volts, instead of the SSR or output module remaining off until the next zero voltage crossover point, load current begins immediately. There is a much steeper di/dt than would occur at a turn-on of 20 volts or less, and there will be a greater heat stress on both junction and load.

From this, it is obvious that a device whose turn-on window does not exceed perhaps 20 volts generates minimal EMI. This is especially true since it is the nature of an SCR and triac to cease conduction only when load current is near zero. Thus, on turn-off, there is no rapidly collapsing magnetic field such as that which occurs when the load circuit is opened at or near peak line voltage. (Such di/dt, of course, generates maximum EMI/RFI.)

Once on, the voltage across the load switch drops to perhaps one to 1.5 volt (**V_2 of Figure 18**), depending on load current. When load current decreases to less than the holding value of the switch, the load goes off and the collapsing magnetic field surrounding the load line generates a counter emf (V_3). Then, as AC voltage crosses zero and begins to increase in magnitude, the switch goes back on (V_1). V_1 is the repetitive turn-on voltage and, in some SSRs and output modules other than P&B, V_1 has been measured to be as high as 25 and even 40 volts. The V_1 of P&B devices typically is 8 to 14 volts, depending on load current. Of course, the higher the V_1, the greater the generated EMI/RFI.

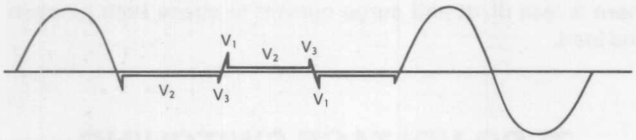


Figure 18
Turn-on and turn-off waveform of SSR load switch.

Zero voltage turn-on can benefit the life of the load in the following manner. A 67 watt, 120 volt AC traffic signal lamp has a hot filament current of 590 milliamps. Cold filament resistance approximates 12 ohms. If power is applied at peak line voltage (i.e., 170 volts), peak inrush current is 14 amps—nearly 24 times the steady-state current! Turn-on at 20 volts, conversely, results in an instantaneous inrush of less than 2 amps—only three times the steady state current. Also, because the lamp filament has several milliseconds in which to heat up before peak voltage is reached, *total* inrush is less than when the filament is switched on at peak voltage. The result is less physical twisting and flexing of the lamp filament. This, of course, contributes to lengthened lamp life.

Pilot-Circuit False Operation

As stated, EMI can generate transient voltages in circuits in proximity to the load line generating the EMI. These transients can appear across circuit components and cause them to false operate. The pilot circuit of some zero voltage turn-on SSRs other than P&B contains components sensitive to EMI induced transients. It is the function of the pilot circuit (**Figure 19**) to turn on the load switch by providing the switch with gate current. Since the pilot circuit is situated between the zero-voltage detection circuit and the load switch, if the pilot circuit does false operate, it may do so at or near peak of the AC sine wave voltage. Should this happen, the load switch junction may be heat stressed. Also, the load circuit of the SSR itself becomes a source of potentially troublesome EMI.

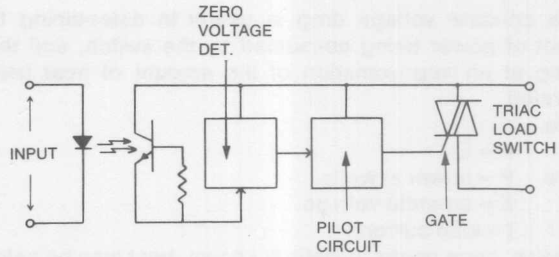


Figure 19
Since the pilot circuit is located after the zero-voltage detection circuit, pilot circuit false operation can negate the zero-voltage function of the SSR.

Because the load switch will remain on only as long as load current is in excess of holding current, the switch will go off when load current approaches the 50/60 Hz. zero current point. Load current may be present only for a few milliseconds, which may seem to be a harmless situation. Indeed, the load may not have time to react. But the perhaps steep di/dt (**Figure 20**) can generate high levels of EMI which may interfere with circuits perhaps not affected by the EMI which caused SSR pilot circuit false operation.

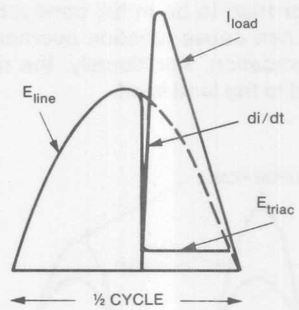


Figure 20
Pilot circuit false operation can result in the load going on at or near peak line voltage.

Because load current may be present for less than one-half of the 50/60 Hz. cycle, this type of false operation is often called *half-cycling.*

Even though the load may not react visibly, half-cycling can cause undue stress on the load or its components. This stress can lead to early failure of the load or components. For example, the dielectric of the capacitor of a capacitor-start motor should not be subjected to the stresses of more than perhaps 20 start-stop cycles per hour, or more than one minute total of on-time per hour. Periodic half-cycling of the off-state motor effectively increases the duty cycle of the capacitor and can result in the accumulation of capacitor heat. Then, normal start-stop cycling can cause thermal stress on the dielectric—shortening the useful life of the capacitor.

Split-phase motors, too, may be adversely affected by half-cycling. In a split-phase motor, the start windings generate heat so rapidly that if the motor stalls it must be taken off line within five seconds. Because of the low resistance of the start windings, half-cycling can cause an I^2R heat rise sufficient to gradually degrade the insulation of the windings. There is no movement of air through the off-state motor and, in time, shorted turns may develop. Most likely the cause of failure will go undetected, and the same relay which caused the problem will be used to switch the replacement motor.

Half-cycling may be harmful to other types of loads as well. For example, periodic half-cycling of cold lamp filaments causes maximum physical twisting and flexing of those filaments and will lead to premature failure of the lamp. Again, upon replacement, the cause of failure may not be realized and the same relay will be used to switch the replacement lamp.

Regarding the life of the SSR itself, as mentioned, an SCR or triac will be in full conduction within 10 microseconds of application of gate current. Thus, in a well designed, zero voltage turn-on SSR, the device will be in full conduction long before peak load current occurs. As a result, the junction operates as cool as possible.

If the load switch is gated on (i.e., false operated) when line voltage is at or near peak, full load current tries to flow the instant the tiniest portion of the junction just begins to conduct (**Figure 21**) and a thermal hot spot can quickly develop. It should be noted that the entire junction does not become conductive instantly. Rather, conduction begins at that point where gate current enters the gate-cathode (or gate-MT_1) junction, and it takes perhaps several microseconds for the entire junction to become conductive. If the junction is subjected to more load current than it can safely handle during the period of time it is coming into full conduction, excessive I^2R heat may cause minimal but permanent degradation of the crystalline structure of the device. In time, when repeatedly subjected to such half-cycling, the cumulative effects of structure degradation will cause the switch to fail.

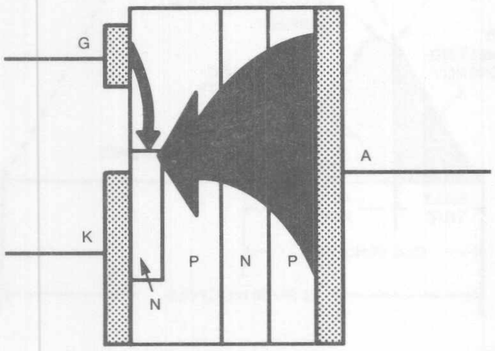


Figure 21
Gating-on the SSR load switch at or near peak line voltage may heat stress the junction.

As shown in **Figure 22**, EMI can be induced into the pilot circuit by way of the relay baseplate or heatsink. Additionally, EMI can be coupled or induced into the pilot circuit through the case itself. In like manner, the input lines can detect EMI, and the potting compound inside the relay can capacitively couple this energy into the pilot circuit.

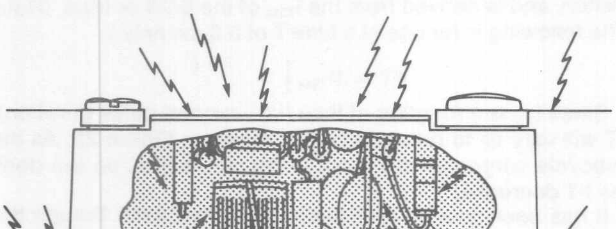


Figure 22
EMI finds its way into the pilot circuit via the SSR case, input terminals and/or baseplate.

Pilot circuit false operation can also be caused by static electrical discharge. For example, if the SSR is mounted to a metal cabinet, a person with a static electrical charge in his body coming in contact with the cabinet can cause the relay to false operate as a result of the static discharge.

EMI/RFI is caused by the operation of motors, lamp switches and ballasts, relays and contactors and, of course, lightning. As shown by the oscillogram in **Figure 23** of a 120 volt AC residential power line taken over a period of 24 hours, numerous peak-to-peak voltages of over 1,000 volts, and a couple over 3,000$V_{p\text{-}p}$ occurred. Notice the repeated bursts of energy on both the left and right side of the picture. If such transients and bursts are present in a residence, they may be even more severe in many commercial and industrial applications.

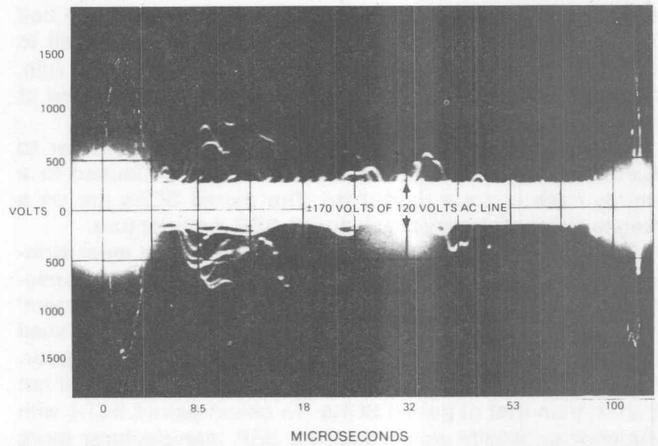


Figure 23.
Oscilloscope recording of residential power line (24 hrs.). Note 3,000V_{pp} at time 2 μsec. (Courtesy G.E. Co., Semiconductor Products Div.)

Pilot circuit false operation may occur at or near peak line voltage, and a severe di/dt problem may exist. If this happens, localized junction overheating may cause a temporary reduction of certain switch characteristics. For example, the switch may temporarily lose its ability to withstand rated line voltage peaks, or it may suddenly become susceptible to load-line dv/dt of less than rated values. In such an event, the relay will turn on, and will not turn off until junction temperature returns to normal.

In most false operation situations the load does not react visibly. Half-cycling only is occurring. Because half-cycling does not manifest itself most SSR users are unaware that half-cycling may be occurring. They are unaware that the relay may suffer early failure as a result of such half-cycling, and that EMI is being generated by the SSR's false operation.

It should be noted that half-cycling is a phenomenon principally associated with zero voltage turn-on SSRs. Reed coupled triac SSRs have no pilot circuit to false operate. And very few transformer coupled triac units are in use. The transformer coupled device *does* have a pilot circuit, and it is subject to EMI false operation. P&B SSRs, however, are far more immune to such false operation than any other SSR on the market. (For test results of immunity to EMI-induced pilot circuit false operation, ask your authorized P&B sales representative for application note 13C203.)

SCR VS. TRIAC LOAD SWITCHING

P&B uses triacs as the load switch of SSRs, whereas some other manufacturers use inverse-parallel connected SCRs (often incorrectly referred to as back-to-back SCRs). Those manufacturers who use SCRs often claim performance superiority over the use of triacs. Likewise, some who use triacs claim performance superiority over those who use SCRs. The fact is a case can be made for the use of either SCRs or triacs.

The paired SCRs used in SSRs are more expensive than a comparable triac and, per unit volume, can conduct more current. Additionally, the SCRs have better blocking voltage than the triac. And commutating dv/dt capability is better than that of a triac. This is because the paired SCRs are physically separate, although they are mounted on the same chip. When one SCR commutates off, it is not affected by the other SCR beginning to conduct.

With a triac, both halves of the device are fabricated onto the same substrate. As gate current is removed and one half of the triac commutates off, the ability of the other half to block rated line voltage is directly affected. Thus, as a rule, triacs do not have as good a commutating dv/dt as that of paired SCRs.

The triac costs less than paired SCRs, and is easier to handle during SSR manufacture. The triac is housed in a sturdy case or on a rigid plate. The paired SCRs are on a fragile chip which may break during SSR manufacture.

The triacs used in P&B solid state relays must meet stringent specifications and should not be considered necessarily indicative of the triacs used in other manufacturers' SSRs. For example, rather than use standard, off-the-shelf triacs whose commutating dv/dt capability may be very poor, P&B uses triacs whose dv/dt capabilities are as good, if not better, than that of paired SCRs. To obtain paired SCRs with superior capability would cost the SSR manufacturer more than the cost of the SCRs presently being used. This, of course, would add to the cost of the relay.

SOLID STATE RELAY OVERCURRENT PROTECTION

The normal failure mode of the load switch of a solid state relay is shorted. That is, SSRs do not fail *safe.* Because of this, it is often desirable to protect the SSR from excessive load-line currents.

To protect the SSR from excessive overcurrents and fault currents, a current-limiting fuse or a magnetic-hydraulic circuit breaker, or both, may be used. Non-current-limiting fuses and thermal circuit breakers are inadequate SSR protection, and serve only to protect the wiring and load.

A current-limiting fuse should be used in circuits where the potential fault current and/or the duration of fault would be in excess of that which the SSR can safely withstand. This type of fuse contains a fusible link surrounded by tightly packed silica sand. When the link melts, the sand immediately fills the void between the remaining sections of the fusible link and thereby quickly extinguishes the arc. In a regular fuse, when an overcurrent causes the link to melt, the arc that ignites between the remaining sections of the link will only extinguish when (in an AC circuit) current crosses zero, or when the gap between the remaining portions of the link becomes too great for arc energy to sustain itself.

Current limiting fuses are capable of interrupting fault currents of tens of thousands of amps, whereas P&B magnetic hydraulic circuit breakers can safely interrupt only 5,000 amps (250V AC, 50/60 Hz). This *interrupt capacity* should not be confused with the fuse or breaker current rating. Although the fuse or breaker may have a rating of, say, 10 amps, during fault conditions thousands of amps may flow until the circuit is opened. If the fuse or breaker is not capable of absorbing the energy of this fault, it may explode.

Fault energy is rated in I^2T. Because of this, fuses and the SCRs and triacs they are designed to protect are also rated in I^2T. The I^2T rating of a fuse is a measure of the amount of energy the fuse will let through to the SCR or triac. The I^2T rating of the SCR or triac is a measure of the amount of energy it will safely handle without damage.

The I in I^2T is the rms amperes of the fault, and the T is the duration (time) of the fault in seconds. I^2T denotes *amp-squared-seconds,* and is a product of not only current and time, but of circuit voltage, as well.

During fuse link melting time, only current and time are involved. However, when the link melts **(Figure 24)** and the arc ignites, circuit voltage takes over, and the I^2T of the arcing time becomes a function of voltage. It is because of this voltage dependency that fuse data sheets list I^2T for different voltages.

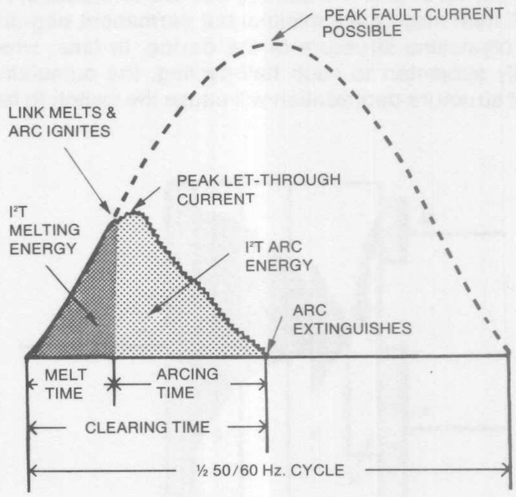


Figure 24
I^2T of current limiting (semiconductor) fuse.

Notice that peak let-through current occurs *after* the link has melted. This peak current occurs because the arc has ignited and the silica sand has not yet filled the gap. As it does fill the gap, the arc begins to extinguish.

The I^2T of the SSR is basically that of the SCR or triac load switch, and is derived from the I_{TSM} of the SCR or triac. (Note: The following is for use at a time T of 8.3 ms only.)

$$I^2T = I^2_{TSM}\frac{T}{2}$$

Since I_{TSM} is a function of time (i.e., current pulse duration), I^2T will vary as to pulse width, as shown in **Figure 25.** As the subcycle surge current pulse width decreases, so too does the I^2T decrease.

It has been proven by industry tests that even though the I^2T of a given fuse for a given pulse duration (clearing time) may be less than that of the SCR or triac it is to protect, when the fuse has a longer pulse width, the I^2T of the fuse may be greater than that of the SCR or triac for the same, longer pulse width. For the SCR or triac to be properly protected, the I^2T of the fuse must be equal to or less than the I^2T of the SSR, *using the same pulse width for both.*

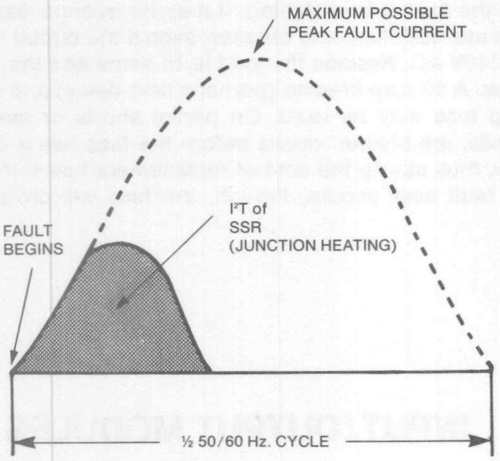


Figure 25
I^2T of SSR must exceed I^2T of protective device for the same width of fault current.

The total clearing time of the fuse being considered for use as protection must be determined and compared with the pulse width of the SSR's I^2T. If clearing time isn't listed on the fuse data sheet along with I^2T and I_{PLT}, it may be determined by:

$$t_c = \frac{3(I^2T)}{I^2_{PLT}}$$

where: t_c = clearing time of fuse
I^2T = amp-squared-seconds
I^2_{PLT} = peak (let-through) current squared

To determine I_{PLT} from fuse tables, total available fault current must be known. This is obtained by dividing source voltage by total circuit impedance, for a shorted load (i.e., line-to-line fault).

Assume the fuse under consideration has a clearing time of 4.2 milliseconds, and an I^2T of 10 amp-squared-seconds. It is to protect a P&B Code 72/74 Model EOM. Since the 72/74 Model EOM has an I^2T of 150 for a pulse duration of 1 millisecond **(Figure 26)**, a fuse that will let through only 10 I^2T will certainly provide adequate protection.

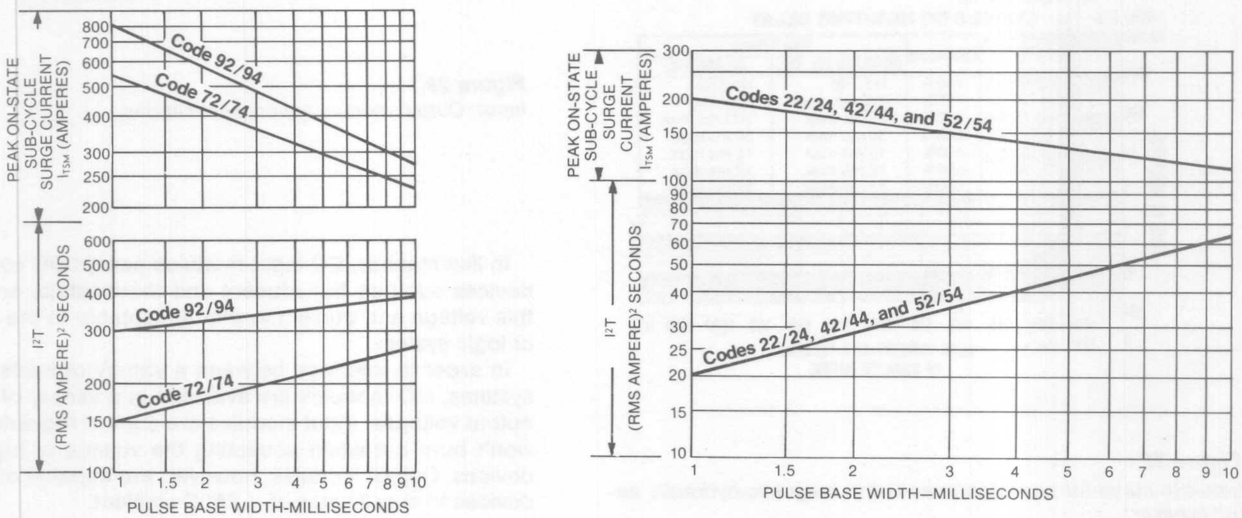


Figure 26
Subcycle surge (non-repetitive) on-state current and I^2T ratings.

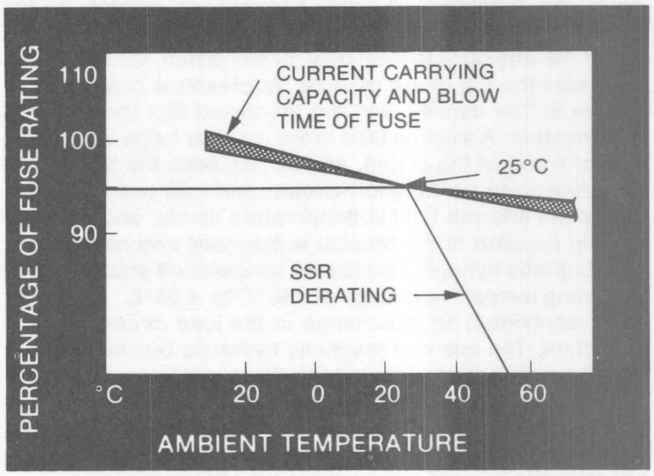


Figure 27
Current carrying capacity of fuse vs. current rating of SSR.

There is a precaution to be observed in matching fuse and SSR characteristics. The current rating and circuit clearing time of the fuse will vary with temperature differently from the current vs. temperature rating of the SSR. As shown in **Figure 27**, the current rating of an SSR is steady to +25°C, and is derated linealy from +25°C to its maximum operating temperature. The ratings of a fuse are for an operating temperature of +25°C but, as shown, at colder temperatures, the ratings increase in value. At warmer temperatures, conversely, the ratings decrease in value.

A 10 amp rated fuse operating in an ambient temperature of −10°C may actually have a rating of 10.4 amps, and may require 4% more time to clear the circuit than at +25°C. These factors should be taken into consideration when matching fuse characteristics to SSR characteristics.

If a thermally stable method of protection is required, a magnetic-hydraulic circuit breaker must be used. A magnetic-hydraulic circuit breaker comprises a coil of wire wound around a cylinder in which a spring-loaded piston is located. Normal load currents flowing in the coil generate insufficient flux to attract the armature (and thus trip

open the breaker contacts). Currents in excess of the breaker rating, however, do generate sufficient flux to attract either the armature immediately, or the piston. When the piston nears the top of the cylinder, its presence causes an increase in flux density, and the increased flux then attracts the armature. A silicone fluid in the cylinder helps control the rate of travel of the piston, and so regulates the trip time of the breaker on partial short-circuits and mild overloads. Because the silicone fluid is temperature stable, and because the trip function of the breaker is magnetic and not thermal, the magnetic hydraulic breaker is temperature stable over its operating temperature range of −40°C to +85°C.

As mentioned, an inductance in the load circuit will help limit di/dt. The coil of a magnetic hydraulic breaker exhibits significant impedance to a steep di/dt, yet has a 60 Hz. impedance of between perhaps 10 milliohms to 10 ohms, depending on model and rating. Thus, the breaker itself helps limit fault current. Plus that, an instantaneous trip breaker will clear the circuit between 2 and 12 milliseconds.

When calculating circuit fault current, don't neglect the impedance of the SSR itself and that of the breaker. Also, don't forget the resistances of terminals and connectors.

A 50 foot length of two-wire #12 A.W.G. copper (100 feet total) has a resistance of 0.162 ohm; enough to limit fault current in a 120V AC circuit to 740 amps. If the on-state voltage drop of the SSR is 1.5 volts, its impedance at normal load current is perhaps .075 ohm. Further, if the breaker coil has an impedance of .10 ohm in the (calculated) presence of a steep fault di/dt, these impedances add up to nearly .340 ohm, in which event 120V AC fault current will be limited to perhaps 350 amps.

In a 48V AC circuit the impedance of the transformer secondary adds to the total circuit impedance, and may limit fault current to 150 amps or less.

The time-trip curve **(Figure 28)** for an instantaneous-trip P&B Model W67 circuit breaker shows that on moderate-to-severe overcurrents, the breaker will clear the circuit between 2 and 12 milliseconds. An SSR whose I_{TSM} is 250 or 300 amps will safely handle 177A rms and 212A rms, respectively, for 16.6 milliseconds. Thus, in a 48 volt circuit, the breaker will provide adequate protection; but in the 120 volt circuit, it won't.

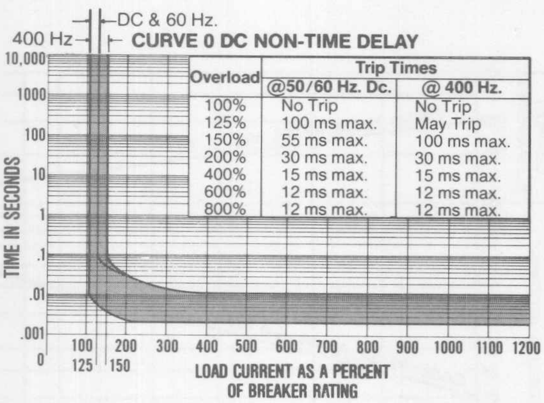


Figure 28
Time-trip curve for an instantaneous-trip magnetic-hydraulic circuit breaker.

In applications where the SSR has a rating greater than that of the load it is switching, it may be economically feasible to use both fuse and breaker, even if the circuit is 120V AC or 240V AC. Assume the load is 10 amps and the SSR is 20 amps. A 10 amp breaker (perhaps time-delay) and a 15 or 20 amp fuse may be used. On partial shorts or moderate overloads, the breaker opens before the fuse has a chance to blow, thus saving the cost of replacement fuses. If a line-to-line fault ever occurs, though, the fuse will protect the SSR.

INPUT/OUTPUT MODULES

Input/output (I/O) modules are printed circuit board mountable, solid state devices for use with microprocessors, TTL, HTL, and MOS logic systems. AC output modules and DC output modules accept the DC output of the processor or logic system and respond by turning on and off the respective AC or DC load.

As shown in **Figure 29**, AC input modules accept AC from devices such as sensors and switches and converts this AC to low voltage, low current DC which it sends to the processor or logic system. The processor or logic system, in turn, uses the DC in its logical functions as determined by its preprogrammed instructions.

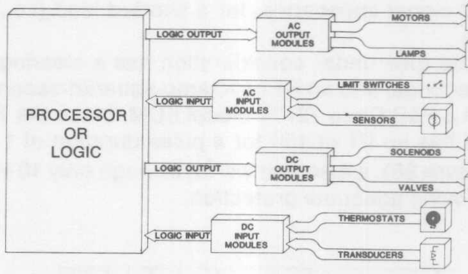


Figure 29
Input/Output module typical applications.

In like manner, DC input modules accept DC voltage from devices such as transducers and thermostats, and convert this voltage and current to that acceptable to the processor or logic system.

In order to interface between a variety of loads and logic systems, I/O modules are available in a variety of input and output voltages. Input modules are current regulated so they won't burn out when accepting the voltage of high current devices. Output modules, however, are capable of switching devices to only 3 amps at +25°C ambient.

P&B AC output modules are zero voltage turn-on solid state relays housed in a small package. DC output modules control the load by use of a transistor. An SCR or triac cannot be used because the turn-off mechanism is a function of load current decreasing to near zero. Direct current, of course, remains steady and does not swing through zero as does AC. A transistor can be made to cease conduction by removal of base current, which is what occurs when control voltage is removed from the DC output module. (Note: A DC output module, in effect, is a DC solid state relay.)

Series-Operation Compatibility

In many applications in which an output module interfaces the logic system and load, it is required that the logic system know when the load is on and when it is off. A signal must be sent back to the processor or logic system which indicates the status of the load.

The most popular method of providing such a signal is by use of an input module **(Figure 30).** When the AC output module (OAC) turns on the load, the appearance of 120 volts across the load turns on the AC input module (IAC). The IAC, in turn, sends a low level signal to the processor or logic system. Likewise, when the ODC turns on its load, the IDC sends a low level signal to the processor or logic system. When the input module is connected to the circuit of the output module in this manner, the operation is said to be in series (even though the output circuit is really a parallel circuit).

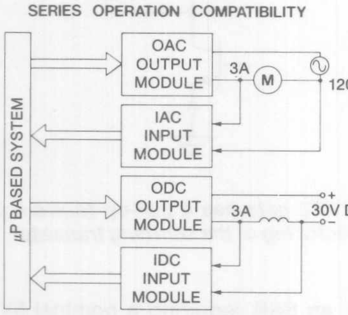


Figure 30

Input modules may be used to sense the condition of the output-module operated load.

Not all I/O modules are series compatible **(Figure 31).** When off, the leakage current of many output modules may be two to four times the dropout current rating of the corresponding input module. Depending on the impedance or resistance of the load in parallel with the input module, the input module may not turn off, even though the load itself goes off. If this happens, a false signal is sent to the logic system. This signal says the load is still on, when it is really off.

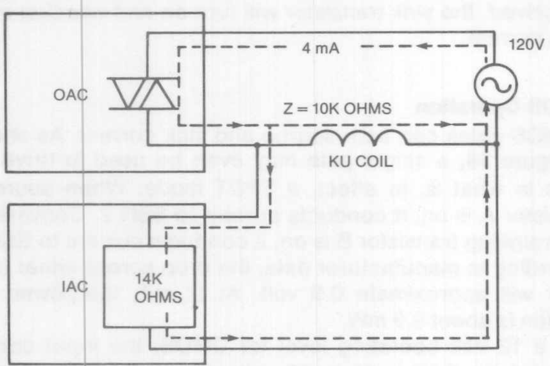


Figure 31

The instant the OAC turns off the load, OAC leakage current divides between load and IAC and may prevent the IAC from turning off.

If leakage of the output module is perhaps 4 mA, and the series connected input module has a dropout rating of, say, 1 mA, current through the parallel circuit is such that the input module will not drop out. This condition only exists when the load has a high impedance or resistance. Such loads are relay and contactor coils, transformers, and solenoids. Many resistive and motor loads do not fall into this category.

P&B I/O modules are fully compatible with each other. Output module leakage currents are equal to or less than the dropout current rating of the corresponding input module. Therefore, no matter the value of parallel impedance or resistance, the input module should always go off when the output module goes off.

CONTROLLING SOLID STATE RELAYS AND OUTPUT MODULES

All solid state relays and I/O modules have minimum and maximum current and voltage ratings which must be observed if reliable operation is to be expected. Occasionally, however, application voltage is in excess of the maximum permissible for the SSR or I/O module. In such applications, a voltage dropping resistor may be connected in series with the relay or module input, as shown in **Figure 32.** The value of resistance is determined by:

$$R = \frac{V_{IN} - V_{PU}}{I_{IN}}$$

Where: I_{IN} = Max. input current at max. pick-up voltage (opto - coupled devices), or nominal input current at max. pick-up voltage (reed-triggered devices).

V_{IN} = DC input voltage

V_{PU} = Pick-up voltage of relay or module

If the resistance value is non-standard, use the next-lowest standard value of resistance. Resistor power rating (watts) is determined by:

$$W_R = (V_{IN} - V_{PU})\,(I_{NOM.})$$

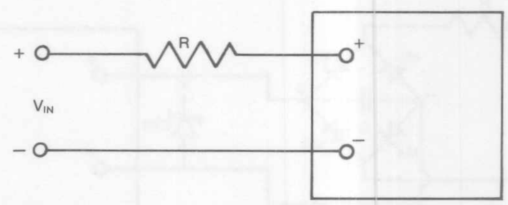


Figure 32

A resistor lowers device input voltage.

Changing Device Pick-Up and Drop-Out Voltage

By use of the appropriate zener diode **(Figure 33),** the pick-up and drop-out voltage of the SSR or I/O module can be changed to a different value. For example, the pick-up point of a 3-32V DC SSR is 3V DC maximum, and the drop-out point is 1.0V DC minimum. Assume it is desired to change the pick-up to 10 volts in a 12V DC application. To determine zener voltage:

$$V_{CR} = V_{PU2} - V_{PU1}$$

Where: V_{CR} = Zener voltage

V_{PU1} = Rated pick-up voltage

V_{PU2} = New pick-up voltage (approx. $0.8V_{IN}$)

That is: $V_{CR} = 10 - 3 = 7$ volts;

so a 7V DC zener diode is to be used. The power rating of the zener diode is the product of the nominal input current of the device and the zener voltage. That is: W = EI.

To determine the new drop-out voltage:

$$V_{DO2} = V_{CR} + V_{DO1}$$

Where: V_{CR} = Zener voltage
V_{DO1} = Rated drop-out voltage
V_{DO2} = New drop-out voltage

Therefore: $V_{DO2} = 7 + 1 = 8$ volts

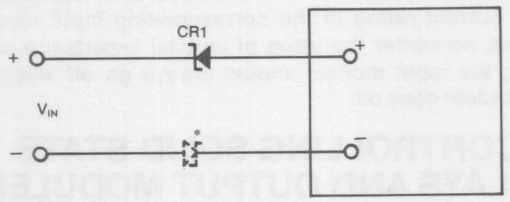


Figure 33
A zener diode changes pick-up and drop-out voltages.

*Alternate position for CR1.

If V_{IN} is in excess of the rated voltage of the device, a resistance may be used to lower the voltage, as shown in **Figure 32.** The equations then become:

$$V_{CR} = V_{PU2} - V_{PU1} - R \times I_{NOM.}$$
$$V_{DO2} = V_{CR} + V_{DO1} + R \times I_{NOM.}$$

NOTE: This procedure is to be used only when applying SSRs or I/O modules in circuits having a voltage greater than the device rating, never when applying the device in a circuit of lower voltage.

Operating DC Input Units from AC

Occasionally the application has only AC available, and it is desired to operate a DC input SSR or I/O module. In such an application, full-wave rectification and filtering is required **(Figure 34).** Filtering is necessary to prevent any ripple voltage from dipping below the device pick-up voltage. Whatever value of capacitance is chosen must not allow ripple to dip below device pick-up voltage.

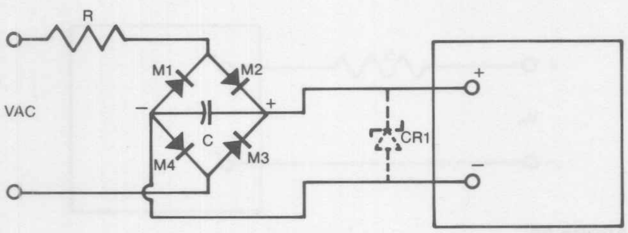


Figure 34
Rectification of AC voltage to operate a DC input solid state relay or I/O module.

The value of resistance is determined by:

$$R = \frac{V_{rms} - V_{IN}}{I_{IN}}$$

Where: I_{IN} = Max. input current at max. pick-up voltage (opto-coupled devices), or nominal input current at max. pick-up voltage (reed-triggered devices).
V_{IN} = DC input voltage
$W_R = (V_{rms} - V_{IN})\ (I_{IN})$
C = 10 μfd., 100VDC
M1 — M4 = Full-wave rectifier, 1A, 100 PIV

NOTE: CR1 is optional and may be used to protect the device from overvoltages on the AC line.

TTL Operation

One of the primary advantages of SSRs and output modules is their compatibility with low-level, solid state logic. Literally any logic gate, buffered or not, capable of delivering the required current and voltage within its maximum power dissipation rating can be used to control an SSR or output module.

Many TTL gates, for example, will safely dissipate 40 mW or more; and the total package will dissipate up to one watt. This gate power must not be confused with relay input power. Whereas an SSR whose input requires 11 mA at 5V DC consumes 55 mW of power, the TTL gate sinking this 11 mA may have a voltage drop of only 0.2 volt, a power consumption of just 2.2 mW!

TTL gates can only sink relay input current, not source it. This is because as shown in **Figure 35,** the sourcing transistor has a pull-up resistance in its collector circuit. Pulling 11 mA through this resistance, in this case 130 ohms, would leave insufficient input voltage to operate the relay.

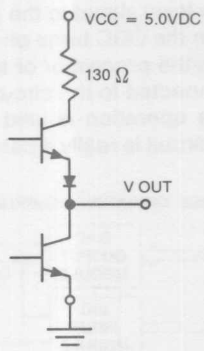


Figure 35
A "totem pole" TTL gate has a pull-up (current limiting) resistance in the collector leg of the sourcing transistor.

For example, an SSR requiring a nominal 5V DC may not operate on less than 4 volts. Typically, the drop across the transistor and diode in **Figure 35** at 11 mA would approximate 0.8 volt; and the drop across 130 ohms is 1.4 volt. This 2.2 volt drop would leave only about 1.8 volts for the relay to operate on—not enough for relay turn-on.

Since TTL gates can only sink current to the relay, and since current sinking is done from a "zero" logic signal, the relay can only be turned on from a "zero" signal. This is contrary to normal relay operation, which prefers that the relay be turned on as a result of a logic "one" signal. To obtain relay actuation from a logical "one" signal, it is necessary to use an inverting gate. With such a gate, when a "one" signal is received, the sink transistor will turn on and conduct relay input current.

CMOS Operation

CMOS gates can both source and sink current. As shown in **Figure 36,** a single gate may even be used to drive two SSRs in what is, in effect, a SPDT mode. When sourcing transistor A is on, it conducts current to SSR 2. Conversely, when sinking transistor B is on, it conducts current to SSR 1. According to manufacturer data, the drop across either transistor will approximate 0.9 volt. At 11 mA, the power dissipation is about 9.9 mW.

At a 12 volt operating level for CMOS, the input control range of the SSR is 10 to 16 volts. Thus, the 0.9 volt drop does not constitute a significant loss. Also, operating at 12 volts, rather than 5 volts, increases the noise immunity of CMOS.

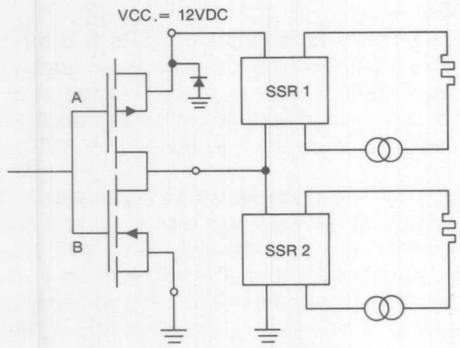


Figure 36
Because CMOS (buffer) gates have no pull-up resistance, they can both source and sink SSR current. Note: The above is not a "true Form C" circuit.

WHEN TO USE SOLID STATE SWITCHING

SSRs should be selected primarily when the following application considerations are of critical importance:

1. Long life. Large number of operations at a rapid rate.
2. Low maintenance.
3. Immunity to shock and vibration.
4. Immunity to the environment (such as humidity, salt spray, and dirt.)
5. Minimal EMI and RFI.
6. IC logic compatibility.
7. No contact bounce, arcing and chattering.
8. No audible noise.
9. Explosion hazard.
10. Lengthened load life.

In contrast, without going into a detailed comparison of all factors of SSRs vs. EMRs, one should remember that SSRs:

- are generally more expensive.
- require greater care in applying.
- have load switches that typically fail in the shorted mode.
- have a nominal on-voltage drop resulting in heat which must be dissipated.
- may have appreciable off-state output leakage current (up to 25mA) which could be a shock hazard.
- are generally available in SPST-NO (1 form A) only.

SELECTING AND APPLYING AC SWITCHING SOLID STATE RELAYS

Solid state relays normally are designed to handle a wide variety of industrial loads with relatively little trouble if even routine consideration to the application has been made in selecting the relay.

Basically, know your application requirements and use the selected SSR within its specified limits and ratings.

1. Load Voltage: Normally knowing whether it is 120 or 240 V 50/60 Hz is adequate unless it is an inductive load where there can be transformed voltages. If the load is a motor and the motor type is known, Potter & Brumfield usually can readily recommend a suitable SSR.

2. Load Current: As long as the load's steady state current is within the SSRs steady state rating for the listed ambient temperature and heatsink, there should be no problem. If there are severe inrush or surge currents greater than 2-10 times the steady state current, select another relay, or consult the factory.

3. Load Types:
Resistive—Consider di/dt
Lamp—Consider di/dt and inrush surge currents. Zero-voltage switching is recommended.
Inductive (solenoid)—Watch for turn-off induced voltage transients and dv/dt.
Motor—Watch for turn-off and transformed voltages.
Transformer—Watch for inrush currents and for turn-off induced voltage transients and dv/dt. (Best to use a peak turn-on SSR, not a zero-voltage SSR.)
Capacitive (start and run windings of motors)—Watch for inrush currents, di/dt, and transformed voltages from motor windings.

4. Relay input: Voltage and current available to operate relay. Voltage and current conditions for which the relay is to *not* operate. Maximum voltage the SSR will encounter. Maximum reverse voltage the SSR input will need to block.

5. Transient immunity: Extreme care based on the requirements of demanding applications was taken into account while designing P&B standard SSRs. Adequate transient immunity to perform and survive in most industrial environments has been built into Potter & Brumfield relays, but some requirements may exceed this.

6. Heatsinking: Ensure that the mounting to which the SSR is to be attached is adequate to keep the SSR base plate temperature below the value listed for the particular current rating on the data sheet. Surfaces should be flat, clean, and coated with a thermally conductive compound.

7. Operating Temperature: What are the minimum and maximum temperature extremes to be encountered? Are these beyond the relays ratings for the expected current ratings?

8. Expected Life: How many operations per year, dwell and repetition rate? How many hours of continuous blocking and conducting?

9. Package Style: ECT, EOT (Q.C. terminals), EOM, ECM (screw terminals), OAC, ODC, IAC, IDC (PCB mounted). Reference data sheets for package dimensions and further details.

10. Random, Zero Voltage, or Peak Voltage Turn-On of Load Switch: Potter & Brumfield's SSRs (reed relay coupled ECM, ECT) are random turn-on devices. Potter & Brumfield optically coupled SSRs (EOM, EOT, OAC) are normally zero voltage, but can be supplied for peak turn-on. Zero voltage devices are recommended to control lamp loads and to reduce EMI and RFI, whereas peak turn-on is recommended for control of transformers. Random turn-on devices are lower cost and perform satisfactorily in most applications.

11. Special recognition such as U.L., C.S.A., and V.D.E.: Such requirements should be called out when applicable, including the particular level category, or rating of that standard.

Review with Potter & Brumfield representative special needs such as rating beyond apparent availability and any known or suspected problem areas.

FACTORS MOST OFTEN CAUSING SOLID STATE RELAY MISAPPLICATION

SSR misapplications most frequently occur due to unawareness of application conditions which exceed the ratings or actual capability of the SSR. These usually relate to one or more of the following areas:

1. Improper or insufficient heatsinking.
2. Inadequate current derating for temperature conditions.
3. Transient breakover voltages (prevalent on 120/240 V 50/60 Hz sources).
4. Loads generating voltages above nominal source value.
5. Voltages appearing across the off-state SSR output terminals, exceeding rated dv/dt.
6. Input controlled turn-on di/dt.
7. Breakover voltage turn-on di/dt.
8. Commutating dv/dt and di/dt.
9. Surge current and resultant thermal stress.
10. Off state leakage current (may be detrimental to the application).
11. EMI-induced, pilot circuit false operation.

The problem areas mentioned are not necessarily of critical concern for all applications. Consideration has been given to these problem areas in the design of P&B SSRs, making them generally suitable for normal industrial use. However, it is always recommended that sample units are evaluated under actual application conditions.

High volume applications may merit special design consideration in order to achieve the most effective cost/performance trade offs. These should be discussed in detail with P&B Application Engineering.

Beware of Zero-Crossover Switching of Transformers

A zero-crossover solid-state relay may be the worst possible method of switching on a transformer or a highly inductive load. Evidence[1] has come to light that zero-crossover turn-on of such loads can cause a surge current of perhaps 10 to 40 *times* the steady state current, whereas turn-on at *peak* voltage results in little or no surge.

Surge currents of such magnitude can seriously shorten the life of the zero-crossover SSR, unless the SSR has a current rating well in excess of the load. They create EMI and RFI (all along the load line) which can destroy logic gates and cause unwanted turn-on of semiconductor switches. Additionally, these surge currents create thermal and mechanical stress on the windings of the inductance and on the transformer core laminations. These stresses can lead to early failure of the device.

The cause of inrush currents of such magnitude is core saturation. Transformers are designed to operate below the knee of the saturation curve of the core material—that is, below point A in **Figure 1**. However, saturation does occur, and when it does, inductance decreases to a very low value. Impedance then drops to little more than the DC resistance of the primary circuit. (This can hold true for any saturable reactance.)

When an inductance whose core contains no remanent magnetism is initially energized at voltage peak, the rate-of-change of current (di/dt) generates maximum counter emf and, as shown in **a** of **Figure 2**, there is no flux surge. However, if voltage is applied at zero, cemf is minimal and "flux doubling" occurs, as shown in **b** of **Figure 2**. This flux doubling is the result of a current surge which can last for several half-cycles.

Remanent magnetism in the core can aggravate this surge condition. It is the nature of core material to retain magnetism to some degree after magnetizing voltage has been removed. If transformer primary voltage is reapplied at zero crossover and in such a direction that the increasing field supports remanent flux, a flux of $2\phi_m + \phi_r$ results (**c** of **Fig. 2**). This flux, of course, is entirely offset from zero, and the core is in deep saturation, as shown by the hysteresis curve in **f** of **Figure 2**. (**d** and **e** are the hysteresis curves for conditions **a** and **b**, respectively.) Inrush current, therefore, is many times normal, as shown in **g** of **Figure 2**, and can last for several half-cycles.

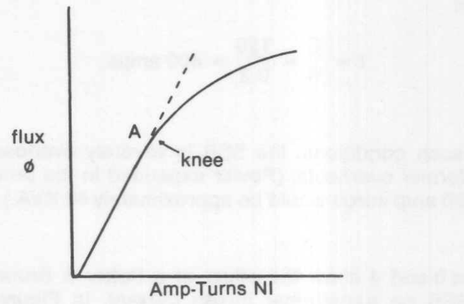


Figure 1

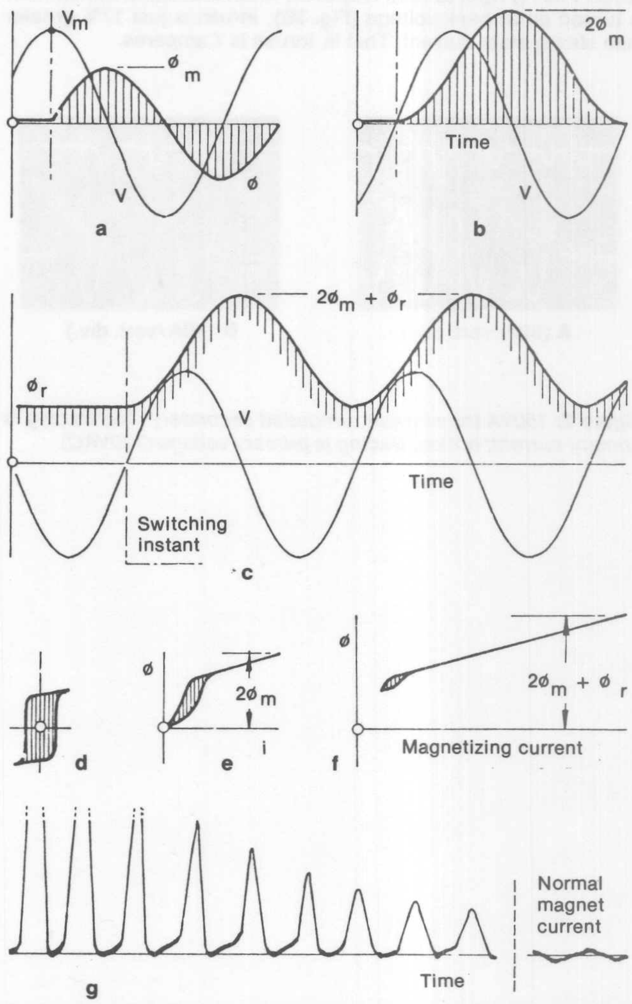


Figure 2

A 150 VA transformer has a 120 volt primary DC resistance of approximately 1.5 ohm, and a 500 VA transformer, a 120 volt primary resistance of approximately 0.3 ohm. One might think a 5 amp zero-crossover SSR would be more than sufficient to switch the current of the 150 VA transformer. However, during core saturation, primary-winding inrush is 80 amps:

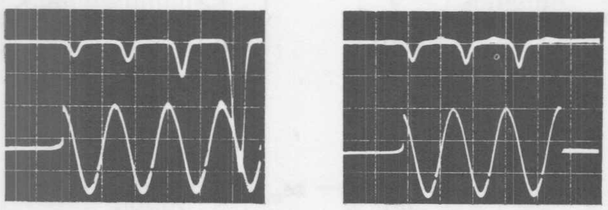
$$I = \frac{E}{R} = \frac{120}{1.5} = 80 \text{ amps.}$$

In the case of the 500 VA transformer, one might think a 10 amp SSR might suffice. But, during core saturation, primary current is 400 amps!

$$I = \frac{E}{R} = \frac{120}{0.3} = 400 \text{ amps.}$$

Under such conditions, the SSR is severely overloaded, and the transformer overheats. (Power expended in the primary during this 400 amp surge would be approximately 40 KVA.)

Figures 3 and **4** show the effect of a Potter & Brumfield 90° turn-on SSR on transformer inrush current. In **Figure 3A**, the transformer secondary is open, and the primary is turned on near zero voltage. A first half-cycle inrush of 200 amps occurs (read scope tracing right to left). However, when that same transformer is turned on at peak voltage **(Fig. 3B)**, inrush is just 17% greater than steady state current. That is, inrush is 7 amperes.



A (50A/vert. div.) **B** (10A/vert. div.)

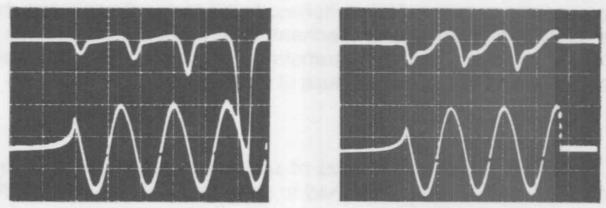
Figure 3: *150VA transformer, unloaded secondary. Top tracing is primary current; bottom tracing is primary voltage (120VAC).*

Figure 4 shows the oscillogram of the same transformer with the secondary connected to a 250 ohm resistor. As can be seen by comparing **Figs. 3A** and **4A**, a loaded secondary has no appreciable effect on primary inrush current.

Surge currents such as those shown in **Figures 3A** and **4A** can be destructive to a zero-crossover SSR.

A "zero-crossover" SSR does not always turn on at precisely zero voltage. It takes perhaps a millisecond or more for the circuitry to react. Therefore, the load switch may not be fully on until load voltage is perhaps 15 to 20 volts. In this event, surge current isn't as great, but it is still potentially destructive. Also, a random turn-on SSR may, at times, turn on at or near zero crossover. The best method of turning on transformers and other saturable, highly inductive loads is by use of a peak voltage turn-on device. Turn-on at peak voltage results in minimal surge, if indeed any surge is present at all.

Zero-crossover SSRs are excellent switches for resistive, capacitive, and non-saturating inductive loads. Even so, inrush current must be taken into consideration. That is, an incandescent lamp can pull a "cold-filament" inrush current of 10 to 20 times the steady-state "hot filament" current. A motor can pull a "locked rotor" currrent of perhaps 6 times its running current. And the inrush of a capacitor, or the inrush of a circuit in which significant stray capacitance is present, is limited solely by the DC resistance of the circuit.



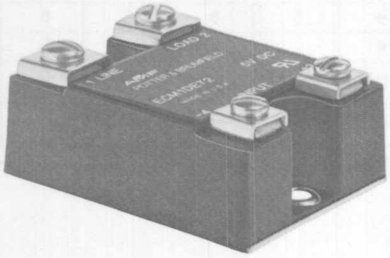
A (50A/vert. div.) **B** (10A/vert. div.)

Figure 4: *150VA transformer, secondary connected across 250 ohm resistor, 240VAC. Top tracing is primary current; bottom tracing is primary voltage (120VAC).*

1. Reference material:
"Alternating Current Machines," Halsted Press, John Wiley & Son. *"Inductively Loaded SSRs Control Turn-On to Eliminate First-Cycle Surges,"* Electronic Design, March 15, 1979. *"Controlling Transformer Inrush Currents," EDN, July, 1966.* *"The Great Zero Cross-over Hoax,"* NARM Proceedings, May, 1974.

ECM series

REED-TRIGGERED TRIAC .075 TO 40 AMPERES HYBRID RELAY



FILE E22575

GENERAL INFORMATION

ECM series hybrid relays are medium power, 120/240V AC, 47-63 Hz. solid state switches controlled and isolated by a reed relay, and packaged for convenient direct chassis mounting. The design is intended to switch AC loads such as solenoids, motors, lamps and transformers through 40 amperes. The advantages of the ECM are long life, high inrush switching capability, and input/output isolation provided by the reed relay.

Protection against false triggering is provided by a dv/dt snubber network across the output switch which restricts the rate of rise of most voltage transients to within acceptable limits.

Both potted and non-potted versions of the ECM are available. Potted units are UL recognized for use in industrial applications. Non-potted units are UL recognized for use in many office equipment and appliance applications.

Some application areas that might require the switching characteristics of the ECM are process controls, instrumentation, alarm devices, machine tools, vending machines, dryers, photocopy equipment and lighting control.

All specifications are applicable for both potted and non-potted versions, except as noted.

ENGINEERING DATA

COIL:
Voltage: 5 to 24V DC
Power:
290 mW nominal for 120V AC, 47-63 Hz, load switching
450 mW nominal for 240V AC, 47-63 Hz, load switching
Duty: Continuous
Operate Time: 1 ms maximum at nominal coil voltage
Release Time: Typical turn-off at first zero crossover
Drop-out Voltage @ 25°C: Greater than or equal to 10% of nominal voltage.
Pick-up Voltage @ 25°C: Less than or equal to 80% of nominal voltage.

GENERAL:
Expected Life: 1 million to 100 million operations, 10 million typical; or 10,000 to 50,000 hours. When operating outside specified min./max. steady state current ratings, consult factory.
Temperature Range: Operating Ambient: −10°C to +80°C (Refer to switch specifications and derating curves.) Storage: −40°C to +85°C.
Approximate Weight: Potted: 3.9 oz. (110 g)
Non-potted: 2.7 oz. (76 g)
Case and Mounting: Refer to dimensional drawing.
Termination: Heavy duty screw terminals
Input: #6-32's
Output: #8-32's
Isolation: 1500V rms, 60 Hz

COIL DATA

Output Voltage Rating	Voltage ±20%	Resistance In Ohms ±10% @ 25°C	Nominal Current (mA)
120V, 47-63 Hz.	5 DC	87	57
	6 DC	125	48
	12 DC	500	24
	24 DC	2000	12
120V, 47-63 Hz. and 240V, 47-63 Hz.	5 DC	56	89
	6 DC	80	75
	12 DC	320	37.5
	24 DC	1280	18.8

ORDERING INFORMATION AND CODE EXPLANATION

Sample Part No. ▶ **ECM 1 D A 7 2 12**

1. **Basic Series:** ECM Solid State Hybrid Relay
2. **Switch Arrangement:** 1 = 1 Form A (SPST-NO)
3. **Coil Control Input:** D = DC
4. **Case style:** A = Potted
   E = Non-Potted
   Refer to outline drawing for dimensions.
5. **Maximum Switch Rating** @ 25°C (Note 2):
   2 = 5A rms 4 = 10A rms 5 = 15A rms 7 = 25A rms 9 = 40A rms
6. **Line Voltage:** 2 = 120V, 47-63 Hz. 4 = 240V, 47-63 Hz.
7. **Coil Voltage:** 5 = 5V 6 = 6V 12 = 12V 24 = 24V

SWITCH U/L RATINGS

File E22575 Magnetic Motor Controllers

Parameter	Voltage (47-63 Hz.)	Units	ECM1DA or E 22	24	42	44	52	54	72	74	92	94
Horsepower	120V	hp			⅛	⅛	¼	¼	½*	½*	1*	1*
	240V	hp				⅓		½		1*		2*
Steady State Current .75 PF—Without Heatsink	120V	A rms	1.5	1.5	4	4	5	5	6	6	9	9
	240V	A rms		1.5		4		5		6		9
Steady State Current .75 PF for ECM package attached to recommended heatsink, NOTE 2	120V	A rms			10	10	15	15	25	25	40	40
	240V	A rms				10		15		25		40

*Code 72/74, non-potted versions and code 92/94, potted and non-potted versions must be mounted to 0.9 C/W heatsink for these U.L. horsepower ratings. In most applications this can be achieved by normal chassis mounting.

HYBRID SOLID STATE SWITCH FACTORY RATINGS

(All ratings are 47-63 Hz. @ +25°C, unless otherwise specified.)

Parameter	Condition	Units	ECM1DA or E 22	24	42	44	52	54	72	74	92	94
Load Voltage NOTE 4	Nominal	V rms	120	240	120	240	120	240	120	240	120	240
	Range	V rms	24-140	24-280	24-140	24-280	24-140	24-280	24-140	24-280	24-140	24-280
Repetitive Blocking Voltage NOTE 1	Minimum	V peak	±200	±400	±200	±400	±200	±400	±200	±400	±200	±400
Non-Repetitive Blocking Voltage NOTE 1	Minimum	V peak	±300	±550	±300	±550	±300	±550	±300	±550	±300	±550
Maximum Steady-State Current at 25°C NOTE 2	I_{T1} Rating with Heatsink	A rms			10	10	15	15	25	25	40	40
	I_{T1} Heatsink Max. Thermal Resistance	°C/W			3.5	3.5	2.0	2.0	1.2	1.2	0.9	0.9
	I_{T2} Rating Without Heatsink, Case A, Potted	A rms	2.5	2.5	5	5	6	6	7	7	9	9
	I_{T2} Rating Without Heatsink, Case E, Potted	A rms	1.4	1.4	4	4	5	5	6	6	7	7
Typical On State Voltage Drop for Maximum Rated Steady State Current at 25°C NOTE 2	@I_{T1}	V peak	1.3	1.3	1.5	1.5	1.5	1.5	1.5	1.5	1.6	1.6
	@I_{T2}	V peak	1.1	1.1	1.2	1.2	1.1	1.1	1.2	1.2	1.3	1.3
Derated A/°C Ambient Rise Above 25°C to a maximum Ambient of 80°C (Refer to switch derating curves) NOTE 2	@I_{T1}	A/°C			.167	.167	.250	.250	.333	.333	.533	.533
	@I_{T2} Case A, Potted	A/°C	.042	.042	.083	.083	.100	.100	.078	.078	.100	.100
	@I_{T2} Case E, Non-Potted	A/°C	.023	.023	.067	.067	.083	.083	.067	.067	.078	.078
Minimum 60 Hz. Load Current NOTE 4	I_{T3}	mA rms	75	75	100	100	150	150	200	200	250	250
Recurrent Surge Current for 100 ms NOTE 3		A peak	15	15	20	20	30	30	50	50	80	80
Non-Repetitive Surge Current for 1 full cycle NOTE 3	100-2000 Expected Operations, 60 Hz.	A peak	80	80	100	100	120	120	250	250	300	300
	100-2000 Expected Operations, 50 Hz.	A peak	72	72	90	90	108	108	225	225	270	270
	2000-20,000 Expected Operations, 60 Hz.	A peak	50	50	60	60	75	75	150	150	200	200
	2000-20,000 Expected Operations, 50 Hz.	A peak	45	45	54	54	68	68	135	135	180	180
Non-Repetitive Surge Current for 10 seconds NOTE 3	2000-20,000 Expected Operations	A peak	15	15	20	20	30	30	50	50	80	80
Commutating dv/dt (inductive Load Switching for Loads of Listed Power Factor (P.F.) or Greater) NOTE 2	Load Current I_{T1} & I_{T2}	PF	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40
	Load Current I_{T3}	PF	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20
Static dv/dt (Ability to Withstand Rate of Rise of Off-State Voltage)	Typical	V/µs	500	500	500	500	500	300	500	300	300	300
	Minimum	V/µs	200	200	200	200	200	100	100	100	100	100
Leakage Current at Nominal 60 Hz. Load Voltage	Typical	mA rms	2.5	5.0	2.5	5.0	5.0	10	5.0	10	5.0	10
	Maximum	mA rms	3.8	7.5	3.8	7.5	7.5	15	7.5	15	7.5	15
I^2t Rating	t = 8.3 ms		26	26	41	41	59	59	260	260	373	373

All specifications are applicable for both potted and non-potted versions, except as noted.

Refer to next page for explanation of NOTES.

NOTE: 1 To promote reliability, the repetitive peak off-state voltage should not exceed 90% of the listed values. The non-repetitive blocking voltage permits (1) a greater degree of immunity from false operation due to transients and (2) turning off inductive loads where ringing can result that produces voltage magnitudes up to twice the peak of the nominal load voltage. For applications that impose high repetitive voltages across the blocking output of the relay (e.g. transformed voltages of start windings of motors), better overall reliability is obtained when these voltages are within the repetitive blocking voltage rating of the relay. Continual blocking of nominal load voltage may create more stress than switching or conducting steady state current loads within the relay ratings. In such cases, the repetitive off state voltage rating of the relay used should be 1.5 to 2 times the peak of the rms load voltage. For these applications review your requirements with the factory.

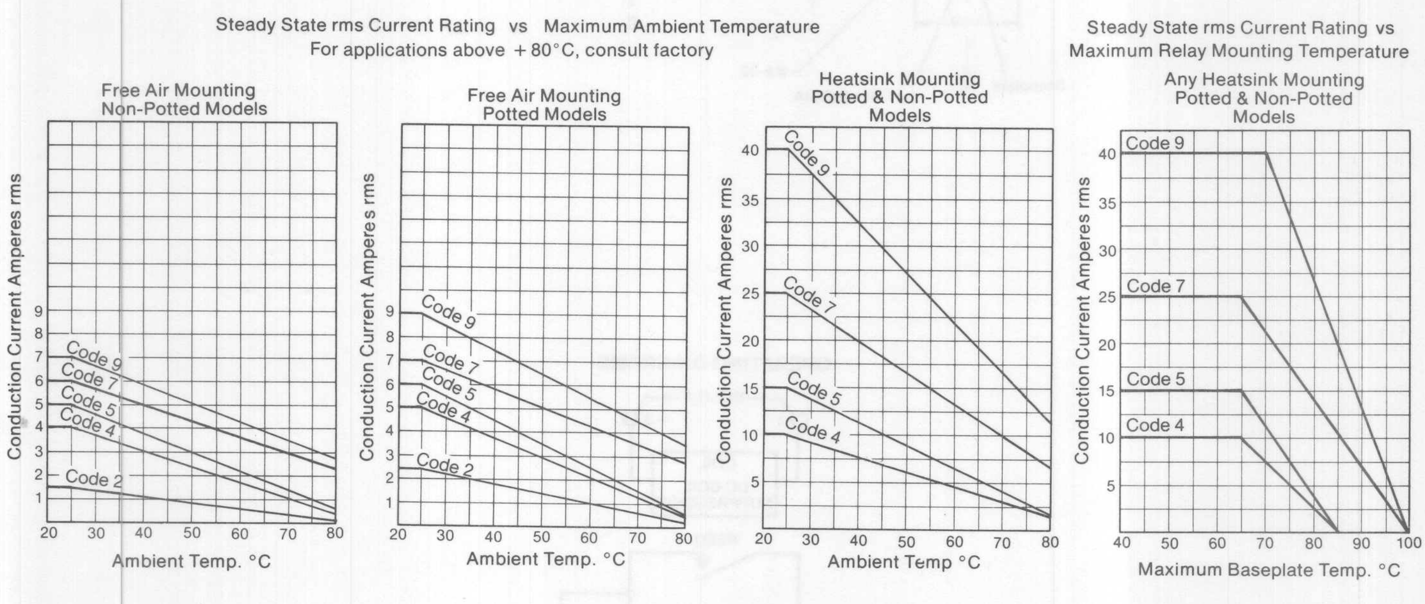
NOTE 2 Steady state current ratings are rms values at 25°C. Refer to switch specifications and the derating curves for limits above 25°C. The derating curves for heatsink mounting are based on usage of a heatsink which meets or exceeds the heatsink thermal impedance requirements as listed in the Hybrid Solid State Switch Factory Ratings table. Thermal joint compound must be used between the relay baseplate and the external heatsink. Aluminum plates of the size listed in the Heatsink Ratings table, with the derating curves, meet or exceed the thermal impedance requirements for the codes with which they are listed.
The derating curves for any heatsink mounting are to be used as a general guideline to insure that the temperature rise of the relay baseplate and, hence the internal component temperatures are not exceeding permissible limits for a particular load current and environmental conditions. Measuring the temperature of the mounting screws on the relay baseplate is usually adequate. Performance and reliability should be considerably enhanced by operating the relay as far below maximum temperature ratings as practical, and by minimizing thermal excursions.

NOTE 3 Input control may be lost during and immediately following the surge current interval due to heating. A current overload may not be repeated until switch temperature has returned to within steady-state rated value. A typical maximum for the repetition rate for current surges is once every three minutes. The rated non-repetitive surge current may produce a thermal stress or fatigue sufficient to cause some degradation to the relay output, whereas the stress resulting from rated recurrent surge current should not cause a noticeable decrease in overall life or increase in failure rate. Non-repetitive surge current stresses have an accumulative effect.

NOTE 4 The conduction angle can gradually decrease as the load current or voltage is reduced beyond the minimum rating. Relay may drop out for load conditions substantially less than this limit. The "on-state" voltage will increase to 15 volts for loads below the holding current of the output triac (10-100mA). Generally, the load current to be switched should be at least 10 times the off-state leakage current. For repetitive switching of highly inductive, low current 240V loads, review your requirements with the factory.

NOTE 5 The "on-state" voltage drop is the value of peak voltage which occurs across the solid state relay output (LINE-LOAD terminals) one quarter cycle after the waveform passes through zero.

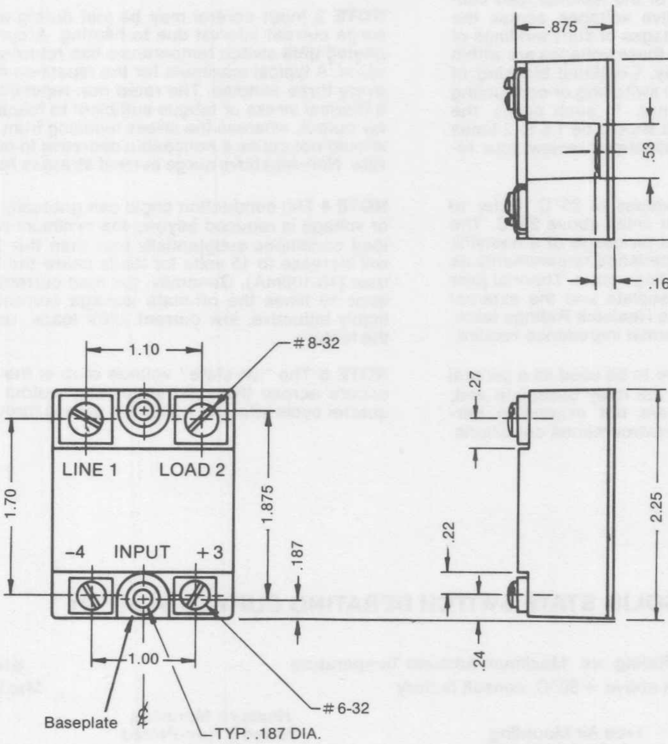
ECM SOLID STATE SWITCH DERATING CURVES (NOTE 2)



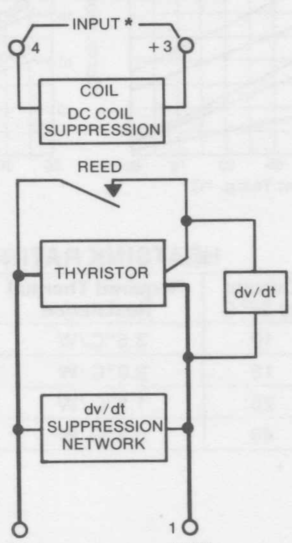
HEATSINK RATINGS

Code	Current @ 25°C	Required Thermal Resistance	Typical Aluminum Heatsink Size
4	10	3.5°C/W	6" x 6" x .125"
5	15	2.0°C/W	10" x 10" x .125"
7	25	1.2°C/W	15" x 15" x .125"
9	40	0.9°C/W	20" x 20" x .125"

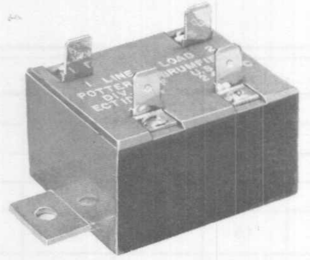
ECM OUTLINE DRAWING



OPERATING DIAGRAMS



*Reversed DC polarity is available



ECT series

REED-TRIGGERED TRIAC .075 to 40 AMPERES HYBRID RELAY

UL File E22575 (DC input only)
CSA File LR15734 (DC input only)

GENERAL INFORMATION

ECT series hybrid solid state relays are medium power, 120/240V AC 47-63 Hz. solid state switches controlled and isolated by a reed relay, and packaged for convenient direct chassis mounting. The design is intended to switch AC loads such as solenoids, motors, lamps, and transformers through 40 amperes. Both AC and DC actuation are available. The advantages of the ECT are long life, high inrush switching capability, and input/output isolation provided by the reed relay.

Protection against false triggering is provided by a dv/dt snubber network across the output switch which restricts the rate of rise of most voltage transients to within acceptable limits.

Some application areas that might require the switching characteristics of the ECT are process controls, instrumentation, alarm devices, machine tools, vending machines, dryers, photocopy equipment, and lighting control.

ENGINEERING DATA

COIL

Voltage: 5 to 48V DC, or 24 and 120V AC, 47-63 Hz.

Power:
DC, 290 mW nominal for 120V AC, 47-63 Hz. load switching.
DC, 450 mW nominal for 240V AC, 47-63 Hz. load switching.
AC, 740 mW nominal for 120V AC, 47-63 Hz. load switching.
AC, 1140 mW nominal for 240V AC, 47-63 Hz. load switching.

Duty: Continuous.

Operate Time:
DC, 2 ms maximum at nominal coil voltage.
AC, 50 ms maximum at nominal coil voltage.

Release Time:
DC, typical turn-off at first zero-crossover.
AC, 150 ms maximum.

Drop-out Voltage @ 25°C: Greater than or equal to 10% of nominal voltage.

Pick-up Voltage @ 25°C: Less than or equal to 80% of nominal voltage.

GENERAL

Expected Life: 1 million to greater than 100 million operations, 10 million typical; or 10,000 to 50,000 hrs. When operating outside specified min./max. steady state current ratings, consult factory.

Temperature Range: Operating Ambient: −10°C to +80°C (Refer to switch specifications and derating curves.) Storage: −40°C to +85°C.

Approximate Weight: 128 grams (4.5 oz.).

Case and Mounting: Refer to dimensional drawing.

Termination: Standard models have .250″ quick connect terminals. .187″ and .205″ quick-connect terminals and available upon special request. Adapters 7AB1 or 7AB2 convert the .250″ quick-connect to screw (6-32) termination.

Isolation: 1500V RMS, 60 HZ (Higher isolation voltage ratings available, consult factory.)

Isolation Resistance: 10^9 ohms.

COIL DATA

Output Voltage Rating	Voltage ±20%	Resistance in Ohms ±10% @ 25°C	Nominal Current (mA)
120V, 47-63 Hz.	5 DC	87	57
	6 DC	125	48
	12 DC	500	24
	24 DC	2000	12
	48 DC	8000	6
	24 AC		13.3
	120 AC		6.2
240V, 47-63 Hz. and 120V, 47-63 Hz.	5 DC	56	89
	6 DC	80	75
	12 DC	320	37.5
	24 DC	1280	18.8
	48 DC	5120	9.4
	24 AC		21
	120 AC		9.5

ORDERING INFORMATION AND CODE EXPLANATION

Sample Part No. ▶ ECT 1 D C 7 2 12

1. **Basic Series:** ECT Solid State Hybrid Relay
2. **Switch Arrangement:** 1 = 1 Form A (SPST-NO)
3. **Coil Control Input:** D = DC A = AC
4. **Case Style:** B or C (Refer to outline drawing for dimensions.)
5. **Maximum Switch Rating** @ 25°C (Note 2):
   2 = 3.5A rms 4 = 10A rms 5 = 15A rms 7 = 25A rms 9 = 40A rms†
6. **Line Voltage:** 2 = 120V, 47-63 Hz. 4 = 240V, 47-63 Hz.
7. **Coil Voltage:** 5 = 5V 6 = 6V 12 = 12V 24 = 24V 48 = 48V 120 = 120VAC

†40 amp models are not CSA certified.

SWITCH U/L RATINGS

File E-22575 Magnetic Motor Controllers

Parameter	Voltage (47-63 Hz.)	Units	ECT1D- 22	24	42	44	52	54	72	74	92	94
Horsepower	120V	hp			⅛	⅛	¼	¼	½	½	1	1
	240V	hp				⅓		½		1		2
Steady State Current .75 PF	120V	A rms	2.5	2.5	4	4	6	6	7	7	9	9
	240V	A rms		2.5		4		6		7		9
Steady State Current .75 PF for ECT Package Attached to Factory Standard Heatsink NOTE 2	120V	A rms			10	10	15	15	25	25	40	40
	240V	A rms				10		15		25		40

HYBRID SOLID STATE SWITCH FACTORY SPECIFICATIONS

OUTPUT CHARACTERISTICS

(All ratings are 47-63 Hz. @ + 25°C, unless otherwise specified.)

Parameter		Condition		Units	ECT1D/A 22	24	42	44	52	54	72	74	92	94
Load Voltage NOTE 4		Nominal		V rms	120	240	120	240	120	240	120	240	120	240
		Range		V rms	24-140	24-280	24-140	24-280	24-140	24-280	24-140	24-280	24-140	24-280
Repetitive Blocking Voltage NOTE 1		Minimum		V peak	±200	±400	±200	±400	±200	±400	±200	±400	±200	±400
Non-Repetitive Blocking Voltage NOTE 1		Minimum		V peak	±300	±550	±300	±550	±300	±550	±300	±550	±300	±550
Maximum Steady-State Current at 25°C NOTE 2	I_{T1}	Rating with Heatsink		A rms	3.5	3.5	10	10	15	15	25	25	40	40
		Heatsink Max. Thermal Resistance		°C/W	3.5	3.5	3.5	3.5	2.0	2.0	1.2	1.2	0.9	0.9
	I_{T2}	Rating Without Heatsink		A rms	2.5	2.5	5	5	6	6	7	7	9	9
Typical On State Voltage Drop for Maximum Rated Steady State Current at 25°C NOTE 2		@ I_{T1}		V peak	1.3	1.3	1.5	1.5	1.5	1.5	1.5	1.5	1.6	1.6
		@ I_{T2}		V peak	1.1	1.1	1.2	1.2	1.1	1.1	1.2	1.2	1.3	1.3
Derated A/°C Ambient Rise Above 25°C to a Maximum Ambient of 80°C (Refer to switch derating curves) NOTE 2		@ I_{T1}		A/°C	.058	.058	.167	.167	.250	.250	.333	.333	.533	.533
		@ I_{T2}		A/°C	.042	.042	.083	.083	.100	.100	.078	.078	.100	.100
Minimum 60 Hz Load Current NOTE 4		I_{T3}		mA rms	75	75	100	100	150	150	200	200	250	250
Recurrent Surge Current for 100 ms NOTE 3				A peak	15	15	20	20	30	30	50	50	80	80
Non-Repetitive Surge Current for 1 full cycle NOTE 3		100-2000 Expected Operations	60 Hz.	A peak	80	80	100	100	120	120	250	250	300	300
			50 Hz.	A peak	72	72	90	90	108	108	225	225	270	270
		2000-20,000 Expected Operations	60 Hz.	A peak	50	50	60	60	75	75	150	150	200	200
			50 Hz.	A peak	45	45	54	54	68	68	135	135	180	180
Non-Repetitive Surge Current for 10 seconds NOTE 3		2000-20,000 Expected Operations		A peak	15	15	20	20	30	30	50	50	80	80
Cummutating dv/dt (Inductive Load Switching for Loads of Listed Power Factor (P.F.) or Greater) NOTE 2		Load Current I_{T1} & I_{T2}		PF	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40
		Load Current I_{T3}		PF	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20
Static dv/dt (Ability to Withstand Rate of rise of Off-State Voltage)		Typical		V/μs	500	500	500	500	500	300	500	300	300	300
		Minimum		V/μs	100	100	100	100	100	100	100	100	100	100
Leakage Current at Nominal 60 Hz. Load Voltage		Typical		mA rms	1.0	5.0	2.5	10	5.0	14	5.0	14	7	14
		Maximum		mA rms	1.5	7.5	3.8	15	7.5	21	7.5	21	10	21
I^2t Rating		t = 8.3 ms			26	26	41	41	59	59	260	260	373	373

Refer to next page for explanation of NOTES.

NOTE: 1 To promote reliability, the repetitive peak off-state voltage should not exceed 90% of the listed values. The non-repetitive blocking voltage permits (1) a greater degree of immunity from false operation due to transients and (2) turning off inductive loads where ringing can result that produces voltage magnitudes up to twice the peak of the nominal load voltage. For applications that impose high repetitive voltages across the blocking output of the relay (e.g. transformed voltages of start windings of motors), better overall reliability is obtained when these voltages are within the repetitive blocking voltage rating of the relay. Continual blocking of nominal load voltage may create more stress than switching or conducting steady state current loads within the relay ratings. In such cases, the repetitive off state voltage rating of the relay used should be 1.5 to 2 times the peak of the rms load voltage. For these applications review your requirements with the factory.

NOTE 2 Steady state current ratings are rms values at 25°C. Refer to switch specifications and the derating curves for limits above 25°C. The derating curves for heatsink mounting are based on usage of a heatsink which meets or exceeds the heatsink thermal impedance requirements as listed in the Hybrid Solid State Switch Factory Ratings table. Thermal joint compound must be used between the relay baseplate and the external heatsink. Aluminum plates of the size listed in the Heatsink Ratings table, with the derating curves, meet or exceed the thermal impedance requirements for the codes with which they are listed.
The derating curves for any heatsink mounting are to be used as a general guideline to insure that the temperature rise of the relay baseplate and, hence the internal component temperatures are not exceeding permissible limits for a particular load current and environmental conditions. Measuring the temperature of the mounting screws on the relay baseplate is usually adequate. Performance and reliability should be considerably enhanced by operating the relay as far below maximum temperature ratings as practical, and by minimizing thermal excursions.

NOTE 3 Input control may be lost during and immediately following the surge current interval due to heating. A current overload may not be repeated until switch temperature has returned to within steady-state rated value. A typical maximum for the repetition rate for current surges is once every three minutes. The rated non-repetitive surge current may produce a thermal stress or fatigue sufficient to cause some degradation to the relay output, whereas the stress resulting from rated recurrent surge current should not cause a noticeable decrease in overall life or increase in failure rate. Non-repetitive surge current stresses have an accumulative effect.

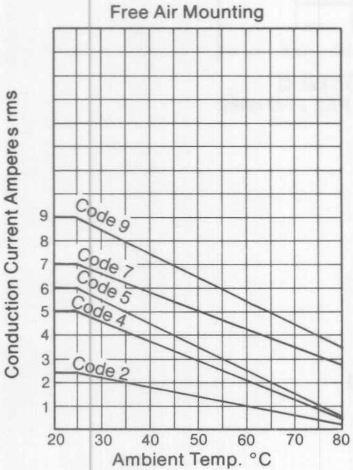
NOTE 4 The conduction angle can gradually decrease as the load current or voltage is reduced beyond the minimum rating. Relay may drop out for load conditions substantially less than this limit. The "on-state" voltage will increase to 15 volts for loads below the holding current of the output triac (10-100mA). Generally, the load current to be switched should be at least 10 times the off-state leakage current. For repetitive switching of highly inductive, low current 240V loads, review your requirements with the factory.

NOTE 5 The "on-state" voltage drop is the value of peak voltage which occurs across the solid state relay output (LINE-LOAD terminals) one quarter cycle after the waveform passes through zero.

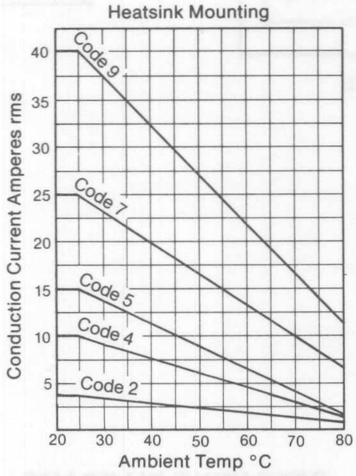
ECT SOLID STATE SWITCH DERATING CURVES (NOTE 2)

Steady State rms Current Rating vs Maximum Ambient Temperature
For applications above +80°C, consult factory

Free Air Mounting

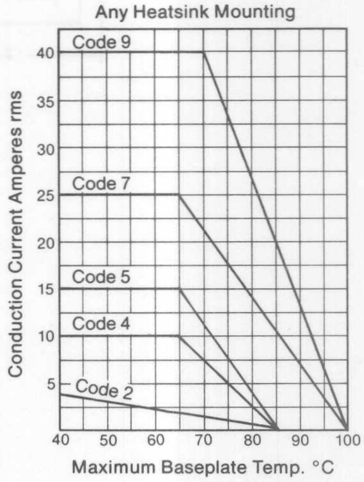


Heatsink Mounting



Steady State rms Current Rating vs
Maximum Relay Mounting Temperature

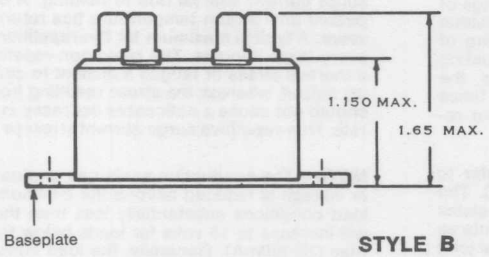
Any Heatsink Mounting



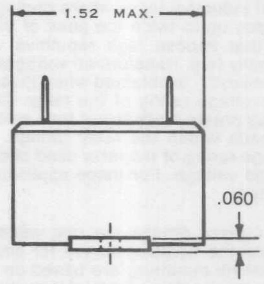
HEATSINK RATINGS

Code	Current @ 25°C	Required Thermal Resistance	Typical Aluminum Heatsink Size
2	3.5	3.5°C/W	6" x 6" x .125"
4	10	3.5°C/W	6" x 6" x .125"
5	15	2.0°C/W	10" x 10" x .125"
7	25	1.2°C/W	15" x 15" x .125"
9	40	0.9°C/W	20" x 20" x .125"

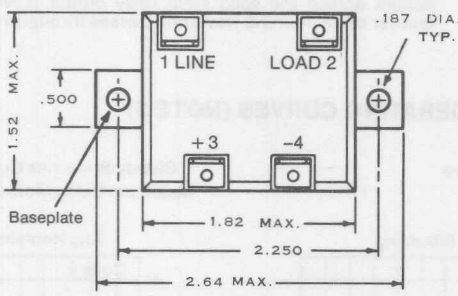
OUTLINE DRAWING



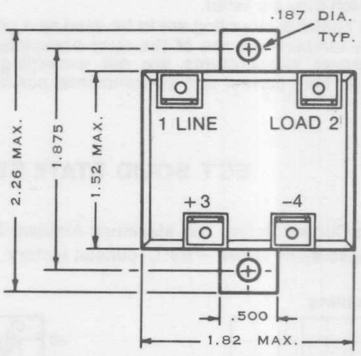
STYLE B



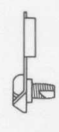
MOUNTING STYLES



STYLE B



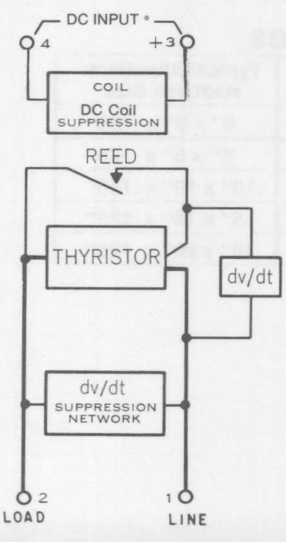
STYLE C
(Same as P&B PRD relay)

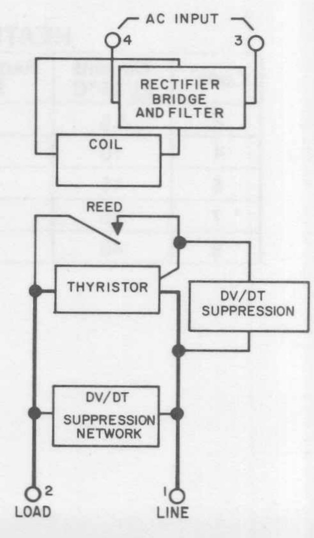


7AB1

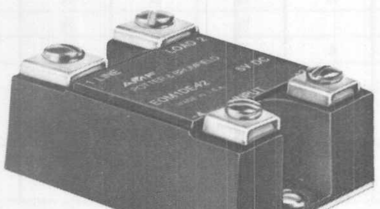
7AB2

OPERATING DIAGRAMS





*Reversed DC polarity is available.



EOM series

.020 TO 25 AMPERES ALL SOLID STATE AC RELAY

Optically Coupled
Zero Crossover Switching
High Transient Noise Immunity

UL File E22575

GENERAL INFORMATION

The EOM is a medium power, 120/240V AC, 47-63 Hz. solid state relay that is controlled by an opto electronic coupler. This design is intended to be used as an ON/OFF switch for loads through 25 amperes. EMI and RFI are greatly reduced due to zero voltage turn-on and zero current turn-off of the load.

Protection against false triggering is provided by a dv/dt snubber network across the output switch which restricts the rate of rise of most voltage transients to within acceptable limits.

An additional safeguard against false triggering is offered on models with a metal oxide varistor which is usually sufficient to clip the amplitude of transient voltages below the peak blocking capability of the output switch.

All models withstand $>4{,}500V_{PP}$ EMI/RFI on the baseplate, and $>3{,}000V_{PP}$ on the case without false operating or half-cycling.

This relay is an ideal component for interfacing between the logic output of TTL, HTL, MOS or microprocessor circuitry and such AC loads as solenoids, motors, lamps, heaters and transformers. Some application areas that might require the switching characteristics of these relays are process controls, instrumentation, alarm devices, machine tools, vending machines, dryers, photocopy equipment and lighting control.

ENGINEERING DATA

Duty: Continuous

Expected Life: 10 million to greater than 100 million operations, or 10,000 to 50,000 hrs. or more. When operating outside specified min./max. steady state current ratings, consult factory.

Temperature Range:
Storage: -40°C to +85°C
Operating Ambient: -30°C to +80°C (Refer to contact specifications and current derating curves.)

Approximate Weight: Potted: 3.9 oz. (110 g)
Non-potted: 2.5 oz. (72 g)

Case and Mounting: Refer to dimensional drawing.

Termination: See dimension drawings.

Immunity to False Operation: $> 4{,}500V_{pp}$ EMI/RFI on relay baseplate; $>3{,}000V_{pp}$ EMI/RFI on relay case. (Note 6)

Isolation: 2500V rms, 60 Hz (Higher isolation voltage ratings are available, consult factory.)

Insulation Resistance: 10^9 ohms.

Operate Time: Typical turn-on at first zero-crossover.

Release Time: Typical turn-off at first zero-crossover.

INPUT SPECIFICATIONS

-30°C to +80°C

Input Voltage Designator	Input Voltage* (V DC)			Max. Input Current (mA DC)	
	Range	Pick-up (Max.)	Drop-out (Min.)	At Rated Pick-up Volts	At Maximum Volts
3-32	3-32	3	1.0	15	35
5	3-5.5	3	1.0	15	25
6	5-7	5	1.0	15	25
12	10-14	10	1.2	15	25
24	20-28	20	2.0	15	25

*Voltage rise and fall rates of 1V/ms or faster.

ORDERING INFORMATION AND CODE EXPLANATION

Sample Part No. ▶ EOM 1 D A 4 2 12

1. **Basic Series:** EOM Solid State Relay
2. **Switch Arrangement:** 1 = 1 Form A (SPST-NO)
3. **Coil Control Input:** D = DC
4. **Case style:** A = Potted
   E = Non-Potted
   Refer to outline drawing for dimensions.
5. **Maximum Switch Rating** @ 25°C (Note 2): †
   2 = 3.5A rms 4 = 10A rms 5 = 15A rms 7 = 25A rms
6. **Line Voltage:** 2 = 120V, 47-63 Hz. 3 = 120V, 47-63 Hz. †† 4 = 240V, 47-63 Hz. 5 = 240V, 47-63 Hz. ††
7. **Input Voltage:** 3-32 = 3-32V 5 = 5V 6 = 6V 12 = 12V 24 = 24V

† Consult factory for other current ratings

†† Has metal oxide varistor. The maximum off-state voltage (peak) should not exceed 200V for voltage code 3, and 375V for code 5.

SWITCH U/L RATINGS

File E22575 Magnetic Motor Controllers

Parameter	Voltage (47-63 Hz.)	Units	EOM1DA or E	22	24	42	44	52	54	72	74
Horsepower	120V	hp				⅛	⅛	¼	¼	½	½
	240V	hp					⅓		½		1
Steady State rms Current .75PF Without Heatsink	120V	A		1.5	1.5	4	4	5	5	6	6
	240V	A			1.5		4		5		6
Steady State rms Current .75PF for EOM package attached to recommended heatsink NOTE 2	120V	A				10	10	15	15	25	25
	240V	A					10		15		25

SOLID STATE SWITCH FACTORY SPECIFICATIONS

OUTPUT CHARACTERISTICS

(All ratings are 47-63 Hz. @ + 25°C, unless otherwise specified.)

	Parameter	Condition	Units	EOM1DA or E	22	24	42	44	52	54	72	74
VOLTAGE	Load Voltage NOTE 4	Nominal	V rms		120	240	120	240	120	240	120	240
		Range	V rms		24-140	24-280	24-140	24-280	24-140	24-280	24-140	24-280
	Repetitive Blocking Voltage NOTE 1	Minimum	V peak		±200	±500	±200	±500	±200	±500	±200	±500
	Non-Repetitive Blocking Voltage NOTE 1	Minimum	V peak		±275	±600	±275	±600	±275	±600	±275	±600
	Typical "On-State" Voltage Drop for Load Current Rating NOTES 2 & 5	@I_{T1}	V peak		±1.3	±1.3	±1.5	±1.5	±1.5	±1.5	±1.5	±1.5
		@I_{T2}	V peak		±1.1	±1.1	±1.2	±1.2	±1.1	±1.1	±1.2	±1.2
	Initial Turn-On Voltage	Typical	V peak		16	16	16	16	16	16	16	16
	Repetitive Turn-On Voltage for Successive Half Cycles	Typical	V peak		6	6	8	8	10	10	12	12
	Static dv/dt (Ability to Withstand Rate of Rise of "Off-State" Voltage)	Typical	V/μs		>500	>500	>500	>500	>500	>500	>500	>500
		Minimum	V/μs		250	250	250	250	250	250	250	250
	Commutating dv/dt Inductive Load Switching for Loads of Listed Power Factor (P.F.) or Greater	@ Current I_{T1} & I_{T2}	P.F.		.40	.40	.40	.40	.40	.40	.40	.40
		@ Current I_{T3}	P.F.		.20	.20	.20	.20	.20	.20	.20	.20
CURRENT	Maximum Steady-State Current at 25°C NOTE 2 — I_{T1}	Max. Rating With Heatsink	A rms		3.5**	3.5**	10	10	15	15	25	25
		Heatsink Max. Thermal Resistance	°C/W		3.5	3.5	3.5	3.5	2.0	2.0	1.2	1.2
	Maximum Steady-State Current at 25°C NOTE 2 — I_{T2}	Max. Rating Without Heatsink	A rms	Case A, Potted	2.5	2.5	5	5	6	6	7	7
		Max. Rating Without Heatsink	A rms	Case E, Non-Potted	1.4	1.4	4	4	5	5	6	6
	Non-Repetitive Surge Current for 1 cycle NOTE 3 — Expected Operations, 60 Hz.	100-2000	A peak		80	80	100	100	120	120	250	250
		2000-20,000	A peak		50	50	60	60	75	75	150	150
	Non-Repetitive Surge Current for 1 cycle NOTE 3 — Expected Operations, 50 Hz.	100-2000	A peak		72	72	90	90	108	108	225	225
		2000-20,000	A peak		45	45	54	54	68	68	135	135
	Non-Repetitive Surge Current for 1 cycle NOTE 3	1s	A peak		20	20	30	30	50	50	75	75
	Recurrent Surge Current NOTE 3	100 ms	A peak		15	15	20	20	30	30	50	50
	Minimum Load Current NOTE 4	I_{T3}	mA rms		20	20	20	20	20	20	20	20
	Leakage Current at Nominal Load Voltage	Typical	mA rms		2	2	2	2	2	2	2	2
		Maximum	mA rms		4	4	4	4	4	4	4	4
	Derating Factor for Current vs. Ambient Rise from 25°C to 80°C (Refer to Switch Derating Curves) NOTE 2	@I_{T1}	A/°C		.058**	.058**	.167	.167	.250	.250	.333	.333
		@I_{T2}	A/°C	Case A, Potted	.033	.042	.067	.083	.080	.10	.078	.078
		@I_{T2}	A/°C	Case E, Non-Potted	.019	.023	.053	.067	.067	.083	.067	.067
	I^2t Rating	t = 8.3 ms			26	26	41	41	59	59	260	260

**Potted model only. Heatsink has no effect on non-potted, current code 2 models.

All specifications are applicable for both potted and non-potted versions, except as noted.

Refer to next page for explanation of NOTES.

NOTE: 1 To promote reliability, the repetitive peak off-state voltage should not exceed 90% of the listed values. The non-repetitive blocking voltage permits (1) a greater degree of immunity from false operation due to transients and (2) turning off inductive loads where ringing can result that produces voltage magnitudes up to twice the peak of the nominal load voltage. For applications that impose high repetitive voltages across the blocking output of the relay (e.g. transformed voltages of start windings of motors), better overall reliability is obtained when these voltages are within the repetitive blocking voltage rating of the relay. Continual blocking of nominal load voltage may create more stress than switching or conducting steady state current loads within the relay ratings. In such cases, the repetitive off state voltage rating of the relay used should be 1.5 to 2 times the peak of the rms load voltage. For these applications review your requirements with the factory.

NOTE 2 Steady state current ratings are rms values at 25 C. Refer to switch specifications and the derating curves for limits above 25 C. The derating curves for heatsink mounting are based on usage of a heatsink which meets or exceeds the heatsink thermal impedance requirements as listed in the EOM Solid State Switch Derating Curves. Thermal joint compound must be used between the relay baseplate and the external heatsink. Aluminum plates of the size listed in the Heatsink Rating table, with the derating curves, meet or exceed the thermal impedance requirement.

The derating curve for any heatsink mounting is to be used as a general guideline to insure that the temperature rise of the relay baseplate and, hence the internal component temperatures are not exceeding permissible limits for a particular load current and environmental conditions. Measuring the temperature of the mounting screws on the relay baseplate is usually adequate. Performance and reliability should be considerably enhanced by operating the relay as far below maximum temperature ratings as practical, and by minimizing thermal excursions.

NOTE 3 Input control may be lost during and immediately following the surge current interval due to heating. A current overload may not be repeated until switch temperature has returned to within steady-state rated value. A typical maximum for the repetition rate for current surges is once every three minutes. The rated non-repetitive surge current may produce a thermal stress or fatigue sufficient to cause some degradation to the relay output, whereas the stress resulting from rated recurrent surge current should not cause a noticeable decrease in overall life or increase in failure rate. Non-repetitive surge current stresses have an accumulative effect.

NOTE 4 The conduction angle can gradually decrease as the load current or voltage is reduced beyond the minimum rating. Relay may drop out for load conditions substantially less than this limit. The "on-state" voltage will increase to 10 volts for loads below the holding current of the output triac (10-100mA). Generally, the load current to be switched should be at least 10 times the off-state leakage current. For repetitive switching of highly inductive, low current 120/240V loads, review your requirements with the factory.

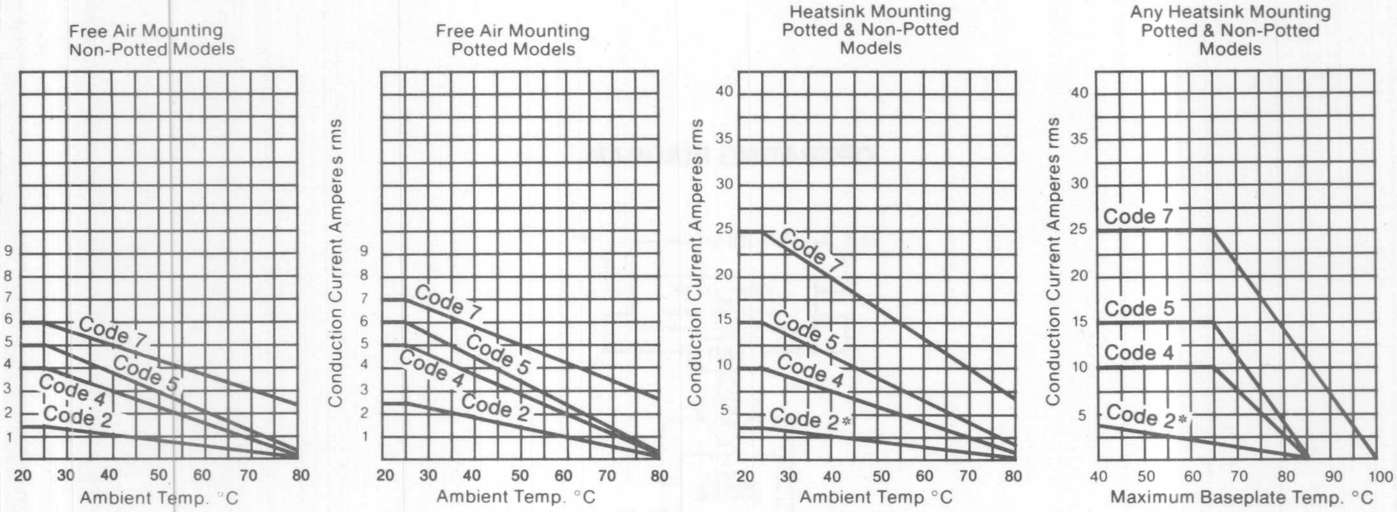
NOTE 5 The "on-state" voltage drop is the value of peak voltage which occurs across the solid state relay output (LINE—LOAD terminals) one quarter cycle after the waveform passes through zero.

NOTE 6 Per NEMA ICS 2-230 (Electrical Noise Immunity Test) these relays typically demonstrate noise immunity of $>10{,}000V_{pp}$.

EOM SOLID STATE SWITCH DERATING CURVES (NOTE 2)

Steady State rms Current Rating vs Maximum Ambient Temperature
For applications above +80°C, consult factory

Steady State rms Current Rating vs Maximum Relay Mounting Temperature



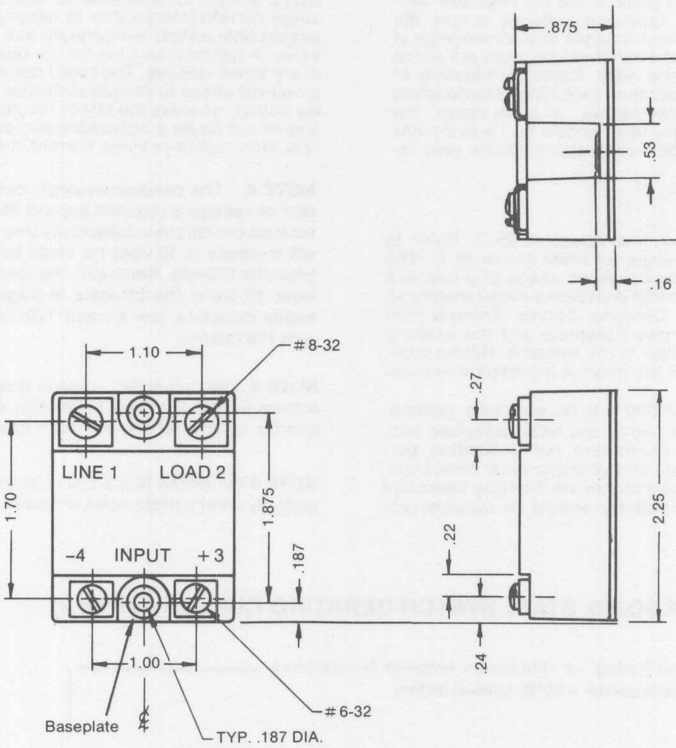
*Potted model only.

HEATSINK RATINGS

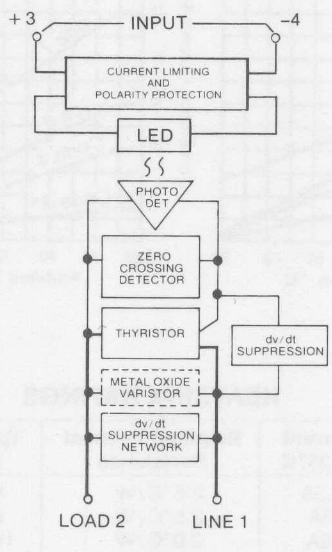
Code	Current @ 25°C	Required Thermal Resistance	Typical Aluminum Heatsink Size
2	3.5A	3.5°C/W	6" x 6" x .125"
4	10A	3.5°C/W	6" x 6" x .125"
5	15A	2.0°C/W	10" x 10" x .125"
7	25A	1.2°C/W	15" x 15" x .125"

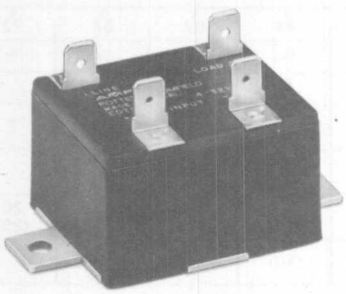
NOTE: Code numbers correspond to Maximum Switch Rating Code in the Ordering Information and Code Explanation table.

OUTLINE DRAWING



OPERATING DIAGRAM





EOT series

.075 TO 40 AMPERES ALL SOLID STATE AC RELAYS

Opto Isolated
Zero Crossover
Switching

File E22575

File LR 15734

GENERAL INFORMATION

The EOT is a medium power, 120/240VAC, 47-63 Hz. solid state switch, controlled and isolated by an opto-electronic coupler. This design is intended to be used as an ON/OFF switch for loads through 40 amperes. EMI and RFI are greatly reduced, due to zero-voltage turn-on and zero-current turn-off of the load.

Protection against false triggering is provided by a dv/dt snubber network across the output switch which restricts the rate of rise of most voltage transients to within acceptable limits.

An additional safeguard against false triggering is offered on models with a metal oxide varistor which is usually sufficient to clip the amplitude of transient voltages below the peak blocking capability of the output switch.

This series presents an ideal component for interfacing between the logic output of TTL, HTL, or MOS circuitry and such AC loads as solenoids, motors, lamps, and transformers. Some application areas that might require the switching characteristics of these relays are process controls, instrumentation, life support equipment, alarm devices, machine tools, vending machines, dryers, photocopy equipment, and lighting control.

The EOT series is UL recognized for use in industrial applications.

ENGINEERING DATA

Duty: Continuous

Expected Life: 10 million to greater than 100 million operations, or 10,000 to 50,000 hrs. or more. When operating outside specified min./max. steady state current ratings, consult factory.

Temperature Range:
Storage: −40°C to +85°C
Operating Ambient: −30°C to +80°C (Refer to contact specifications and current derating curves.)

Approximate Weight: 6.0 oz. (170 grams)

Case and Mounting: Refer to dimensional drawing.

Termination: See dimension drawings.

Isolation: 1500V rms, 60 Hz (Higher isolation voltage ratings are available, consult factory.)

Insulation Resistance: 10^9 ohms.

Operate Time: Typical turn-on at first zero-crossover.

Release Time: Typical turn-off at first zero-crossover.

Transient Noise Immunity: >3000 V (Peak-to-Peak) Per NEMA ICS 2-230 (Note 6)

INPUT SPECIFICATIONS

−30°C to +80°C

Input Voltage Designator	Input Voltage* (V DC) Range	Pick-up (Max.)	Drop-out (Min.)	Input Current (mA DC) At Rated Pick-up Volts (Max.)	At Maximum Volts (Max.)
3-32	3-32	3	0.8	15	20
5	4- 6	4	0.8	11	18#
6	5- 8	5	0.8	11	18
12	10-16	10	1.2	11	18
24	18-32	18	2.0	11	18

*Voltage rise and fall rates of 1V/ms or faster.

16 ma max. @5.5 VDC
8 ma typ. @ 5.0 VDC.

ORDERING INFORMATION AND CODE EXPLANATION

Sample Part No. ▶ EOT 1 D C 4 2 12

1. **Basic Series:** EOT Solid State Relay
2. **Switch Arrangement:** 1 = 1 Form A (SPST-NO)
3. **Coil Control Input:** D = DC
4. **Case Style:** B or C (Refer to outline drawing for dimensions.)
5. **Maximum Switch Rating** @ 25°C (Note 2):†
   2 = 3.5A rms 4 = 10A rms 5 = 15A rms 7 = 25A rms 9 = 40A rms§
6. **Line Voltage:** 2 = 120V, 47-63 Hz. 3 = 120V, 47-63 Hz. †† 4 = 240V, 47-63 Hz. 5 = 240V, 47-63 Hz. ††
7. **Input Voltage:** 3-32 = 3-32V 5 = 5V 6 = 6V 12 = 12V 24 = 24V

†Consult factory for other current ratings.

††Has metal oxide varistor. The maximum off-state voltage (peak) should not exceed 200V for voltage code 3, and 375V for voltage code 5.

§40 amp model is not UL recognized or CSA certified

SWITCH U/L RATINGS
File E22575 Magnetic Motor Controllers

Parameter	Voltage (47-63 Hz)	Units	EOT1DB/C 22	24	42	44	52	54	72	74
Horsepower	120V	hp			1/10	1/10	1/8	1/8	1/3	1/3
	240V	hp				1/4		1/3		3/4
Steady State Current .75 PF—No Heatsink	120V	A rms	2 (2.5)	2 (2.5)	4 (5)	4 (5)	5 (6)	5 (6)	7	7
	240V	A rms		2 (2.5)		4 (5)		5 (6)		7
Steady State Current .75 PF for EOT Package Attached to Recommended Heatsink. NOTE 2	120V	A rms			(10)	(10)	12 (15)	12 (15)	20 (25)	20 (25)
	240V	A rms				(10)		12 (15)		20 (25)

NOTE: Values in parenthesis are pending.

SOLID STATE SWITCH FACTORY SPECIFICATIONS
OUTPUT CHARACTERISTICS
(All ratings are 47-63 Hz. @ +25°C, unless otherwise specified.)

Parameter		Condition	Units	EOT1DB/C 22	24	42	44	52	54	72	74	92	94
Load Voltage NOTE 4		Nominal	V rms	120	240	120	240	120	240	120	240	120	240
		Range	V rms	24-140	24-280	24-140	24-280	24-140	24-280	24-140	24-280	24-140	24-280
Repetitive Blocking Voltage NOTE 1		Minimum	V peak	±200	±500	±200	±500	±200	±500	±200	±500	±200	±500
Non-Repetitive Blocking Voltage NOTE 1		Minimum	V peak	±300	±600	±300	±600	±300	±600	±300	±600	±300	±600
Maximum steady-state load current rating NOTE 2	I_{T1}	Rating with Heatsink	A rms	3.5	3.5	10	10	15	15	25	25	40	40
		Heatsink Max. Thermal Resistance	°C/W	3.5	3.5	3.5	3.5	2.0	2.0	1.2	1.2	0.9	0.9
	I_{T2}	Without Heatsink	A rms	2.5	2.5	5	5	6	6	7	7	9	9
Non-Repetitive Surge Current for 1 full cycle NOTE 3	100-2000 Expected Operations	60 Hz	A peak	80	80	100	100	120	120	250	250	300	300
		50 Hz	A peak	72	72	90	90	108	108	225	225	270	270
	2000-20,000 Expected Operations	60 Hz	A peak	50	50	60	60	75	75	150	150	200	200
		50 Hz	A peak	45	45	54	54	68	68	135	135	180	180
		1 s	A peak	20	20	30	30	50	50	75	75	100	100
Recurrent Surge Current NOTE 3		100 ms	A peak	15	15	20	20	30	30	50	50	80	80
Minimum Load Current NOTE 4		I_{T3}	mA rms	75	75	100	100	150	150	200	200	250	250
Maximum "On-State" Voltage Drop for Load Current Rating NOTE 2		@I_{T1}	V peak	1.3	1.3	1.5	1.5	1.5	1.5	1.5	1.5	1.6	1.6
		@I_{T2} & I_{T3}	V peak	1.1	1.1	1.2	1.2	1.1	1.1	1.2	1.2	1.3	1.3
Leakage Current at Nominal Load Voltage		Typical	mA rms	2.5	5	2.5	5	2.5	5	2.5	5	2.5	5
		Maximum	mA rms	5	10	5	10	5	10	5	10	5	10
Static dv/dt (Ability to withstand Rate of Rise of "Off-State" Voltage)		Minimum	V/μs	100	100	100	100	100	100	100	100	100	100
		Typical	V/μs	250	250	250	250	250	250	250	250	250	250
Initial Turn-On Voltage		Typical	V peak	16	16	16	16	16	16	16	16	16	16
Repetitive Turn-On Voltage For Successive Half Cycles		Typical	V peak	8	8	10	10	12	12	14	14	14	14
Commutating dv/dt (Inductive load switching for loads of listed power factor (PF) or greater. NOTE 2		Current I_{T1} & I_{T2}	PF	.40	.40	.40	.40	.40	.40	.40	.40	.40	.40
		Current I_{T3}	PF	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20
Derating Factor for Current vs Ambient Rise from 25°C to 55°C. (Refer to Contact Derating Curves.) NOTE 2		@I_{T1}	A/°C	.058	.058	.167	.167	.250	.250	.333	.333	.533	.533
		@I_{T2}	A/°C	.042	.042	.083	.083	.100	.100	.078	.078	.100	.100
I^2t Rating		t = 8.3 ms		26	26	41	41	59	59	260	260	373	373

Refer to next page for explanation of NOTES.

NOTE: 1 To promote reliability, the repetitive peak off-state voltage should not exceed 90% of the listed values. The non-repetitive blocking voltage permits (1) a greater degree of immunity from false operation due to transients and (2) turning off inductive loads where ringing can result that produces voltage magnitudes up to twice the peak of the nominal load voltage. For applications that impose high repetitive voltages across the blocking output of the relay (e.g. transformed voltages of start windings of motors), better overall reliability is obtained when these voltages are within the repetitive blocking voltage rating of the relay. Continual blocking of nominal load voltage may create more stress than switching or conducting steady state current loads within the relay ratings. In such cases, the repetitive off state voltage rating of the relay used should be 1.5 to 2 times the peak of the rms load voltage. For these applications review your requirements with the factory.

NOTE 2 Steady state current ratings are rms values at 25°C. Refer to switch specifications and the derating curves for limits above 25°C. The derating curves for heatsink mounting are based on usage of a heatsink which meets or exceeds the heatsink thermal impedance requirements as listed in the Solid State Switch Factory Ratings table. Thermal joint compound must be used between the relay baseplate and the external heatsink. Aluminum plates of the size listed in the Heatsink Ratings table, with the derating curves, meet or exceed the thermal impedance requirements for the codes with which they are listed.
The derating curves for any heatsink mounting are to be used as a general guideline to insure that the temperature rise of the relay baseplate and, hence the internal component temperatures are not exceeding permissible limits for a particular load current and environmental conditions. Measuring the temperature of the mounting screws on the relay baseplate is usually adequate. Performance and reliability should be considerably enhanced by operating the relay as far below maximum temperature ratings as practical, and by minimizing thermal excursions.

NOTE 3 Input control may be lost during and immediately following the surge current interval due to heating. A current overload may not be repeated until switch temperature has returned to within steady-state rated value. A typical maximum for the repetition rate for current surges is once every three minutes. The rated non-repetitive surge current may produce a thermal stress or fatigue sufficient to cause some degradation to the relay output, whereas the stress resulting from rated recurrent surge current should not cause a noticeable decrease in overall life or increase in failure rate. Non-repetitive surge current stresses have an accumulative effect.

NOTE 4 The conduction angle can gradually decrease as the load current or voltage is reduced beyond the minimum rating. Relay may drop out for load conditions substantially less than this limit. The "on-state" voltage will increase to as much as 3 volts for loads less than the holding current of the output triac (10-100mA). For even lower load currents, less than the holding current of the pilot circuitry (5-10mA), the relay will turn off. Generally, the load current to be switched should be at least 10 times the off-state leakage current. For repetitive switching of highly inductive, low current 240V loads, review your requirements with the factory.

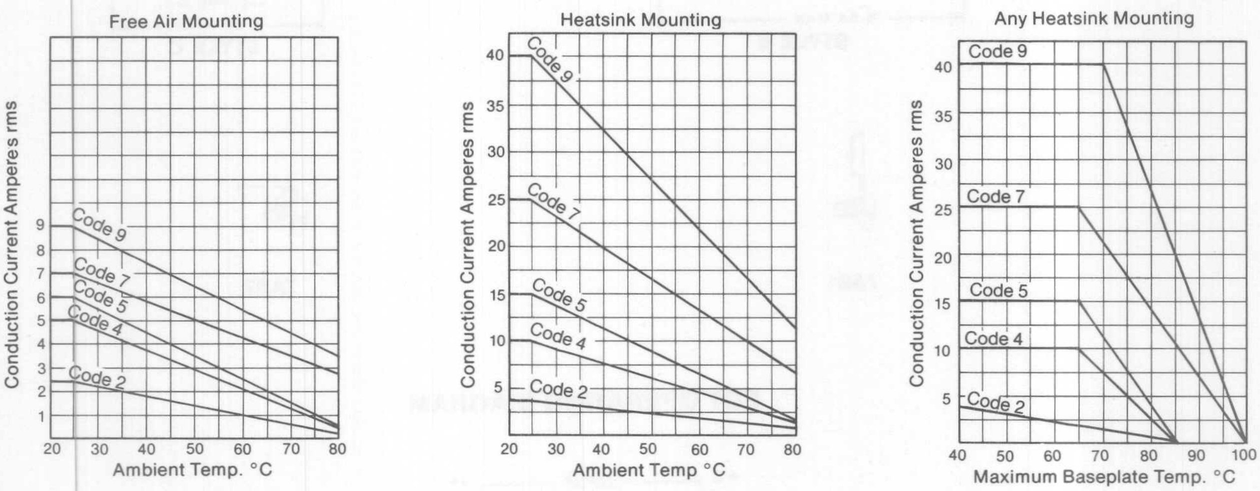
NOTE 5 The "on-state" voltage drop is the value of peak voltage which occurs across the solid state relay output (LINE-LOAD terminals) one quarter cycle after the waveform passes through zero.

NOTE 6 Per NEMA ICS 2-230 (Electrical Noise Immunity Test) these relays typically demonstrate noise immunity of $>10{,}000V_{pp}$.

EOT SOLID STATE SWITCH DERATING CURVES (NOTE 2)

Steady State rms Current Rating vs Maximum Ambient Temperature
For applications above +80°C, consult factory

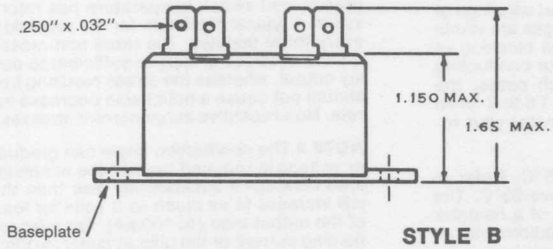
Steady State rms Current Rating vs Maximum Relay Mounting Temperature



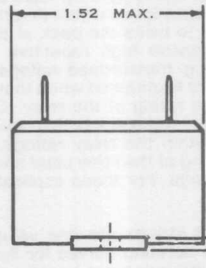
HEATSINK RATINGS

Code	Current @ 25°C	Required Thermal Resistance	Typical Aluminum Heatsink Size
2	3.5	3.5° C/W	6" x 6" x .125"
4	10	3.5°C/W	6" x 6" x .125"
5	15	2.0°C/W	10" x 10" x .125"
7	25	1.2°C/W	15" x 15" x .125"
9	40	0.9°C/W	20" x 20" x .125"

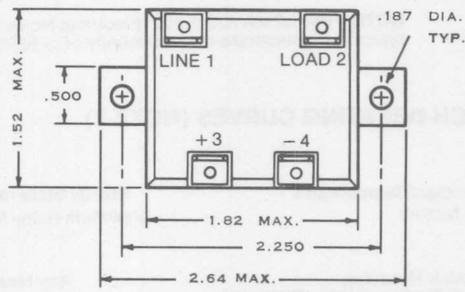
EOT DIMENSIONS



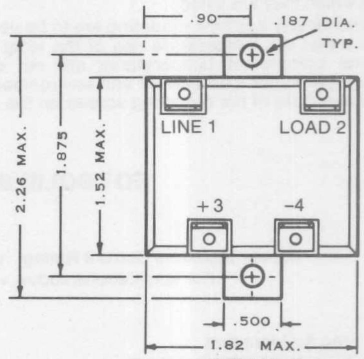
STYLE B



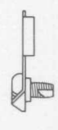
MOUNTING STYLES



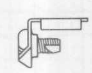
STYLE B



STYLE C

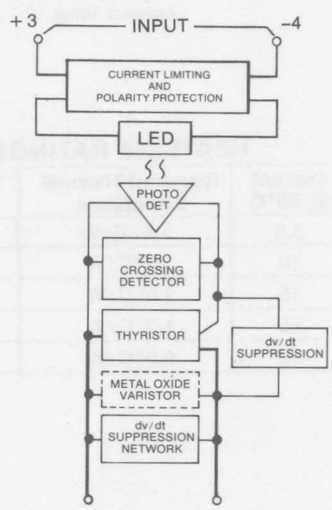


7AB1

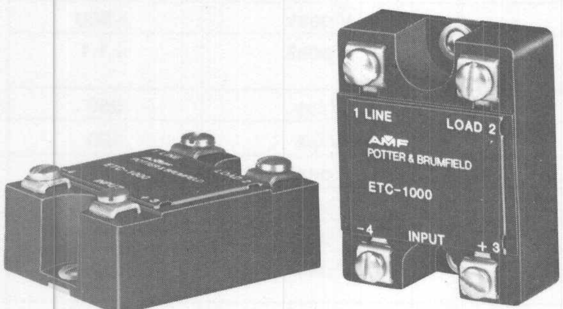


7AB2

EOT OPERATING DIAGRAM



Note: Standard models have .250" quick-connect terminals. .187" and .205" quick-connect terminals are available on special request. Adapters 7AB1 and 7AB2 convert the .250" quick-connnect terminals to #6-32 screw terminals.



ETC series

SOLID STATE RELAYS FOR TRAFFIC LIGHT CONTROL

GENERAL INFORMATION

ETC-1000/1100 solid state relays are primarily for use as ON/OFF switches to control traffic lights. These relays are controlled by an opto electronic coupler and will switch load requirements up to 10 amperes at 75°C when the device is mounted in a traffic light control relay assembly. The design is intended to meet NEMA, California and New York traffic signal standards.

Protection against false triggering is provided by a dv/dt snubber network across the output switch which restricts the rate of rise of most voltage transients to within acceptable limits.

The ETC-1000/1100 will withstand induced transients >4500 Vpp EMI/RFI on the baseplate and >3000 Vpp EMI/RFI on the case without false operating or half-cycling.

ENGINEERING DATA

Duty: Continuous
Expected Life: Typically greater than 100 million operations or greater than 50,000 hrs.
Temperature Range:
Storage: -40°C to +85°C.
Operating Ambient: -40°C to +80°C.
Approximate Weight: 2.5 oz. (72 grams)
Case and Mounting: Refer to dimensional drawing.

Termination: See dimension drawings.
Immunity to False Operation: >4500 Vpp EMI/RFI on relay baseplate; >3000 Vpp EMI/RFI on relay case (NEMA ICS2-230).
Isolation: 1500V rms, 60 Hz/2000VDC (Input to Output and Input—Output to base).
Insulation Resistance: 10^9 ohms.
Operate Time: Typical turn-on at first zero voltage crossover.
Release Time: Typical turn-off at first zero current crossover.

INPUT SPECIFICATIONS

-40°C to +80°C

Parameter	Units	Condition	ETC-1000	ETC-1100
Must Operate*	VDC	Maximum	18	12
Must Release*	VDC	Minimum	8	8
Maximum Operate	VDC		32	32
Current @ 24 VDC	mA	Maximum	10	10
Reverse Input	VDC	Maximum	32	32

*Voltage rise and fall rates of 1 v/ms or faster.

ORDERING INFORMATION

Part Number	Description	Recognition
ETC-1000	Solid state relay	Meets California traffic signal standards
ETC-1100	Solid state relay	Meets New York traffic signal standards

OUTPUT CHARACTERISTICS

(All ratings are 47-63 Hz. @ +25, unless otherwise specified.)

	Parameter		Condition	Units	Limit
VOLTAGE	Load Voltage**			V rms	24-140
VOLTAGE	Repetitive Blocking Voltage**		Minimum	V peak	±200
VOLTAGE	Non-Repetitive Blocking Voltage**		Minimum	V peak	±500
VOLTAGE	"On-State" Voltage Drop @ 10 Amps **Note 1**		Typical	V peak	±1.1
VOLTAGE	Static dv/dt (Ability to Withstand Rate of Rise of "Off-State" Voltage)		Typical	V/μs	250
			Minimum	V/μs	100
VOLTAGE	Initial Turn-On Voltage **Note 2**		Typical	V peak	16
			Maximum	V peak	28
VOLTAGE	Repetitive Turn-On Voltage For Successive Half Cycles **Note 2**		Typical	V peak	8
			Maximum	V peak	14
CURRENT	Maximum Steady State Current **Note 3**		75°C Amb.	A rms	10
CURRENT	Non-Repetitive Surge Current for One Cycle	Expected Operations	100-2000	A peak	250
			2000-20000	A peak	150
CURRENT	Non-Repetitive Surge Current		1 sec.	A peak	75
CURRENT	Recurrent Surge Current		100 ms	A peak	50
CURRENT	Minimum Load Current **Note 4**			mA rms	50
CURRENT	Leakage Current @ 120 V rms		Typical	mA rms	1.5
			Maximum	mA rms	4

**Over operating temperature range.

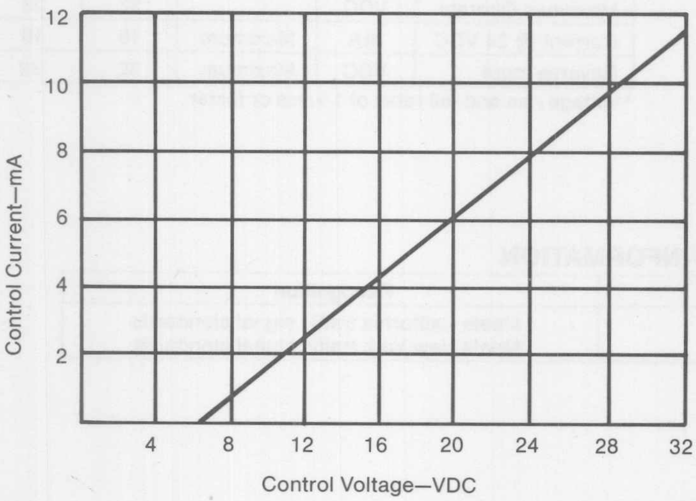
NOTE 1 The "on-state" voltage drop is the value of peak voltage which occurs across the solid state relay output (Line-Load terminals) one quarter cycle after the waveform passes through zero.

NOTE 2 Turn-on voltages are for a 10A, 120V tungsten lamp load.

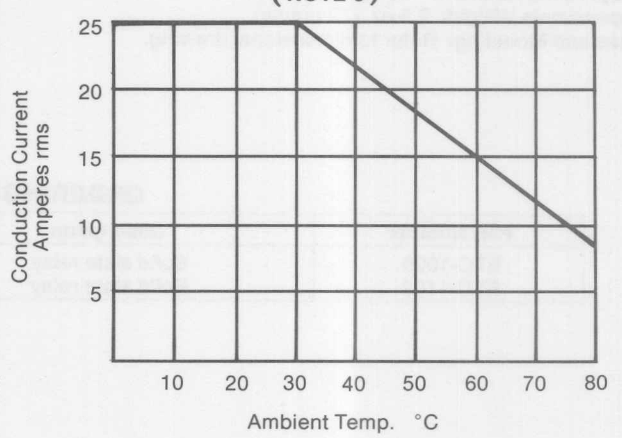
NOTE 3 This rating is based on the relay mounted on a heatsink having a maximum thermal impedence of 2.4°C/W. In many applications this can be achieved by mounting in a traffic light control relay assembly. Thermal joint compound must be used between the relay baseplate and mounting surface.

NOTE 4 For load currents below the holding current of the output tripac (10-100 mA), the "on-state" voltage will increase to typically 3 volts since the pilot SCR is switching the load.

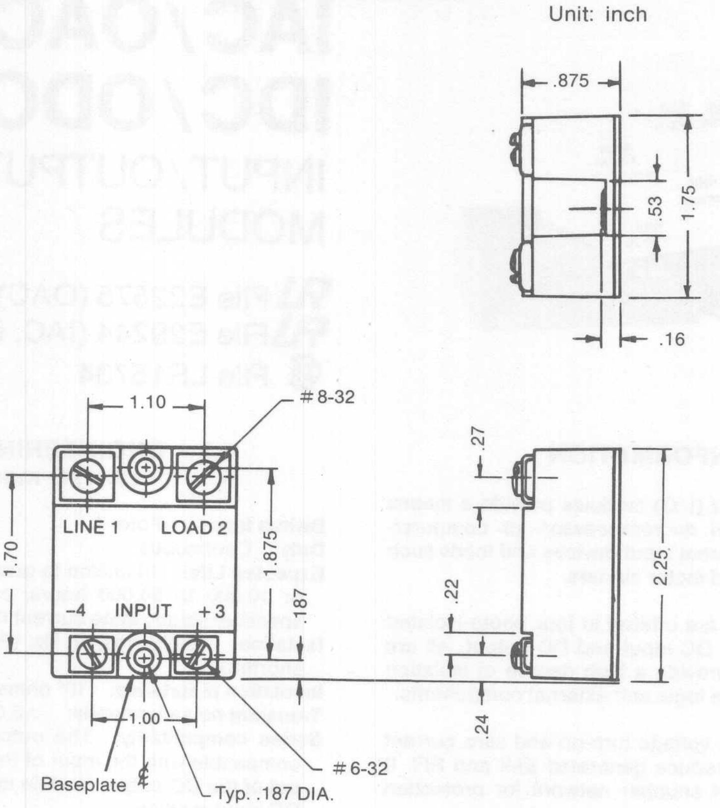
Typical Control Current vs. Control Voltage @25°C Ambient



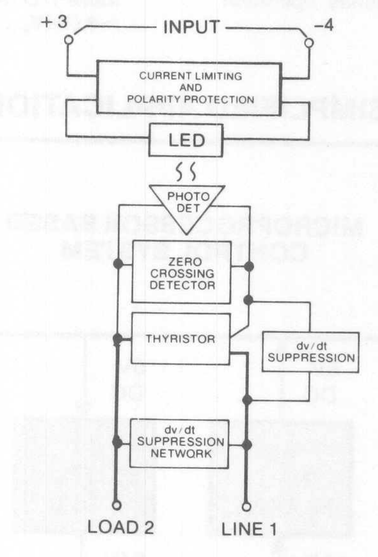
Steady State rms Current Rating vs. Maximum Ambient Temperature
(NOTE 3)

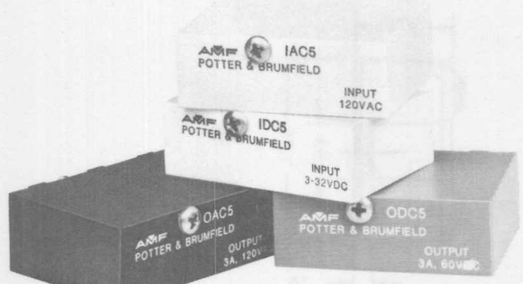


OUTLINE DRAWING



OPERATING DIAGRAM





IAC/OAC IDC/ODC

INPUT/OUTPUT MODULES

File E22575 (OAC)
File E29244 (IAC, IDC, & ODC)
File LR15734

GENERAL INFORMATION

Potter & Brumfield input/output (I/O) modules provide a means of reliably interfacing between microprocessor- or computer-based control systems and external input devices and loads such as switches, sensors, valves and motor starters.

These solid state I/O modules are offered in four photo-isolated versions: AC input, AC output, DC input and DC output. All are color coded by function and provide a high degree of isolation and noise immunity between the logic and external components.

AC output module utilizes zero voltage turn-on and zero current turn-off of the load to greatly reduce generated EMI and RFI. It also features an internal dv/dt snubber network for protection from voltage transients on the line.

For user convenience all modules are packaged in the industry standard plug-in enclosure with captive hold down screw. This allows modules to be interchanged in the field quickly and easily without disturbing wiring.

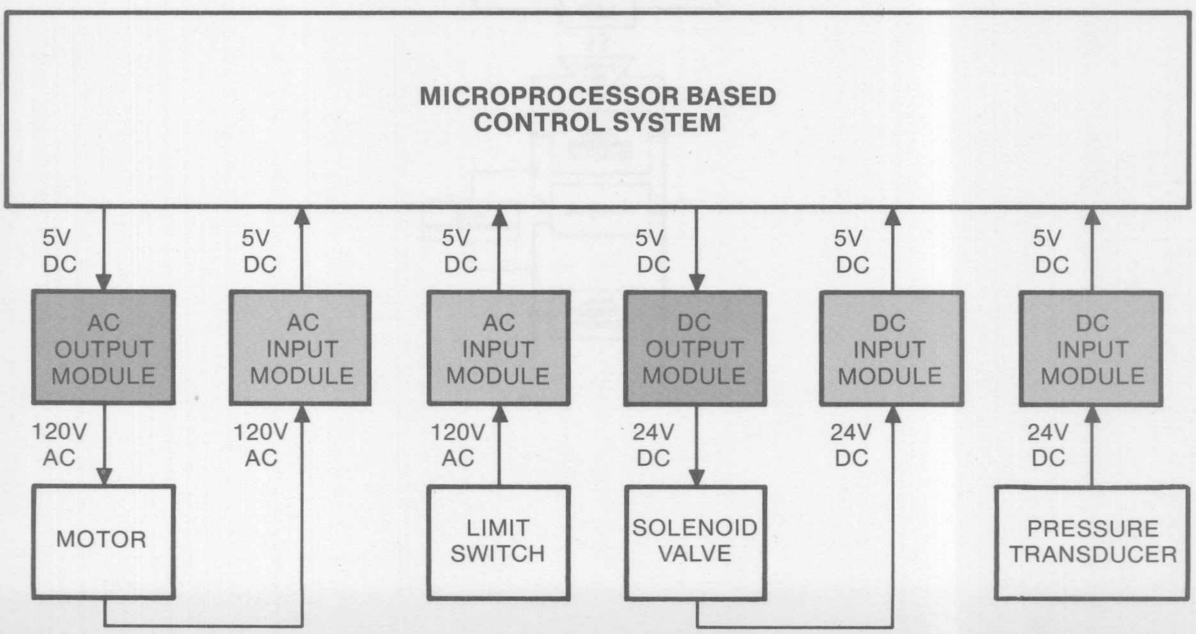
On modules of the same voltage type, AC or DC, the output of output modules is compatible with the input of input modules. This makes these modules ideally suited for series operation applications.

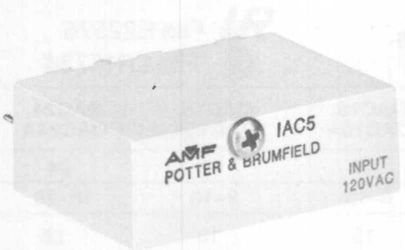
ENGINEERING DATA (all I/O modules)

Switch form: 1 Form A
Duty: Continuous
Expected Life: 10 million to greater than 100 million operations; or 10,000 to 50,000 hours, or more, when operating within specified steady state current ratings.
Isolation: 4000V rms, 60 Hz. (Pins 1 & 2 shorted, pins 3, 4 & 5 shorted)
Insulation resistance: 10^9 ohms
Transient noise immunity: $>3{,}000V_{p\text{-}p}$*
Series compatibility: The output of the AC output module is compatible with the input of the AC input module, and the output of the DC output module is compatible with the input of the DC input module.
Storage temperature: -40°C to +85°C
Operating temperature: -30°C to +80°C
Approximate weight: 1.2 oz. (34 grams)

* *Transient noise immunity is the ability to withstand external noise without triggering the load switch or transmitting the noise. Per NEMA ICS 2-230 (Electrical noise immunity test) these I/O modules typically demonstrate noise immunity of* $>8{,}000V_{p\text{-}p}$.

SIMPLIFIED APPLICATION





IAC
AC Input Modules

File E29244†

File LR15734

Input Specifications
(-30 C to +80 C)

Parameter	Condition	Units	IAC5, IAC10, IAC15, IAC24, IAC30	IAC5A, IAC10A, IAC15A, IAC24A, IAC30A	IAC5E, IAC10E, IAC15E, IAC24E, IAC30E
Input Voltage	Range	VAC	90-140	180-280	10-36
Pick-Up Voltage	Max.	VAC	90	180	10
Drop-Out Voltage	Min.	VAC	25	50	3
Input Current at Rated Pick-Up Voltage	Max.	mA	8	6	7
Input Current at Max. Voltage	Max.	mA	12	8	24
Drop-Out Current at Min. Drop-Out Voltage	Max.	mA	2.0	1.5	1.1
	Typ.	mA	1.7	1.2	.9
Input Resistance	Typ.	K Ohms	14	41	1.8
Operation from DC Input Voltage	Range	VDC	95-150	200-300	10-36

Output Specifications
(+25°C, unless otherwise specified)

Parameter	Condition	Units	IAC5, IAC5A, IAC5E	IAC10, IAC10A, IAC10E	IAC15, IAC15A, IAC15E	IAC24, IAC24A, IAC24E	IAC30, IAC30A, IAC30E
Output Transistor Blocking Voltage	Max.	VDC	30	30	30	30	30
Output Current*	Max.	mA DC	100	100	100	100	100
Output Leakage with No Input	Max. @ 30VDC	µA DC	100	100	100	100	100
Output Voltage Drop at Max. Current	Max.	VDC	0.4	0.4	0.4	0.4	0.4
Logic Supply Voltage	Nom.	VDC	5	10	15	24	30
	Range	VDC	3-6	6–13	9–18	18–28	27–33
Logic Supply Current (LED in Series with Nom. Logic Voltage)	Typ.	mA DC	10	10	10	10	10
Turn On Time	Max.	ms	20	20	20	20	20
Turn Off Time	Max.	ms	20	20	20	20	20

†Models with "E" suffix are not UL/CSA.
*Inductive loads should be diode suppressed.

OAC
AC Output Modules

File E22575
File LR15734

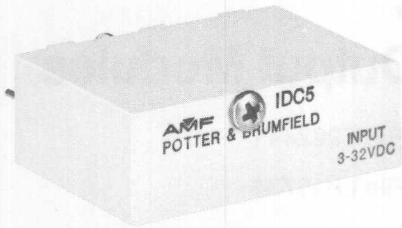
Input Specifications (−30°C to +80°C)

Parameter	Condition	Units	OAC5, OAC5A	OAC10, OAC10A	OAC15, OAC15A	OAC24, OAC24A	OAC30, OAC30A
Input Voltage	Nom.	VDC	5	10	15	24	30
	Range	VDC	3–6	6–13	9–18	18–28	27–33
Reverse Voltage Protection	Max.	VDC	6	13	18	28	33
Pick-Up Voltage	Max.	VDC	3	6	9	18	27
Drop-Out Voltage	Min.	VDC	1	1	1	1	1
Input Current at Rated Pick-Up Voltage	Max.	mA	12	14	14	14	13
Input Current at Max. Voltage	Max.	mA	35	35	35	25	20
Input Current (LED in series with Nom. Voltage)	Typ.	mA	14	18	18	14	12
Input Resistance	Typ.	Ohms	180	430	680	1500	2400

Voltage rise and fall rates of 1 v/ms or faster.

Output Specifications (47 to 63 Hz. @ +25°C, unless otherwise specified)

Parameter	Condition	Units	OAC5, OAC10, OAC15, OAC24, OAC30	OAC5A, OAC10A, OAC15A, OAC24A, OAC30A
Load Voltage	Nom.	V rms	120	240
	Range	V rms	24-140	24-280
Repetitive Blocking Voltage	Min.	V peak	±200	±400
Non-Repetitive Blocking Voltage	Min.	V peak	±275	±400
Steady State Load Current (See Derating Curves)	Max. (I_1)	A rms	3	3
	Min. (I_2)	mA rms	20	20
Current Derating Factor for Rise from +25°C to +80°C Ambient	@ I_1	A/°C	.040	.040
Non-Repetitive Surge Current For 1 Cycle for the Expected Number of Operations Listed	60 Hz. 100–2K Ops.	A peak	80	80
	60 Hz. 2K–20K Ops.	A peak	48	48
	50 Hz. 100–2K Ops.	A peak	72	72
	50 Hz. 2K–20K Ops.	A peak	43	43
Non-Repetitive Surge Current for 1 second	Max.	A peak	20	20
Repetitive Surge Current	100 ms	A peak	9	9
Leakage Current at Nom. Load Voltage.	Max.	mA rms	2	1.5
	Typ.	mA rms	1.7	1.2
On-State Voltage Drop.	Max. @ I_1	V peak	1.5	1.5
Initial Turn-On Voltage	Typ.	V peak	20	20
Repetitive Turn-On Voltage for Successive Half Cycles	Typ.	V peak	16	16
Static dv/dt	Min.	V/µs	200	200
	Typ.	V/µs	400	400
Commutating dv/dt (Inductive load switching for loads of listed power factor (PF) or greater)	@ I_1	PF	.40	.40
	@ I_2	PF	.20	.20
Turn On Time (Next Zero Voltage)	Max.	Cycle	½	½
Turn Off Time (Next Zero Current)	Max.	Cycle	½	½
I^2t Rating	t = 8.3 ms		26	26



IDC
DC Input Modules

UL File E29244†

CSA File LR15734

Input Specifications
(−30°C to +80°C)

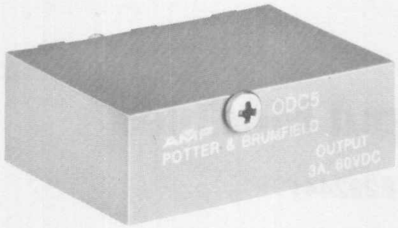
Parameter	Condition	Units	IDC5, IDC10, IDC15, IDC24, IDC30	IDC5F, IDC10F, IDC15F IDC24F, IDC30F
Input Voltage	Range	VDC	3-32	3-32
Reverse Voltage Protection	Max.	VDC	32	32
Pick-Up Voltage	Max.	VDC	3	3
Drop-Out Voltage	Min.	VDC	1	1
Input Current at Rated Pick-Up Voltage	Max.	mA	10	10
Input Current at Max. Voltage	Max.	mA	15	15
Input Current at Rated Drop-Out Voltage	Max.	mA	1	1

Voltage rise and fall rates of 1 v/ms or faster.

Output Specifications
(+25°C, unless otherwise specified)

Parameter	Condition	Units	IDC5	IDC10	IDC15	IDC24	IDC30	IDC5F	IDC10F	IDC15F	IDC24F	IDC30F
Output Transistor Blocking Voltage	Max.	VDC	30	30	30	30	30	30	30	30	30	30
Output Current*	Max.	mA DC	100	100	100	100	100	100	100	100	100	100
Output Leakage with No Input	Max. @ 30VDC	μA DC	100	100	100	100	100	100	100	100	100	100
Output Voltage Drop at Max. Current	Max.	VDC	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Logic Supply Voltage	Nom.	VDC	5	10	15	24	30	5	10	15	24	30
	Range	VDC	3.6	6-13	9-18	18-28	27-33	3-6	6-13	9-18	18-28	27-33
Logic Supply Current (LED in Series with Nom. Logic Voltage)	Typ.	mA DC	10	10	10	10	10	10	10	10	10	10
Turn On Time	Max.	ms	5	5	5	5	5	.05	.05	.05	.05	.05
Turn Off Time	Max.	ms	5	5	5	5	5	.1	.1	.1	.1	.1

†Models with "F" suffix are not UL/CSA.
*Inductive loads should be diode suppressed.



ODC
DC Output Modules

File E29244†

File LR15734

Input Specifications
(-30°C to +80°C)

Parameter	Condition	Units	ODC5, ODC5A	ODC10, ODC10A	ODC15, ODC15A	ODC24, ODC24A	ODC30, ODC30A
Input Voltage	Nom.	VDC	5	10	15	24	30
	Range	VDC	3–6	6–13	9–18	18–28	27–33
Reverse Voltage Protection	Max.	VDC	6	13	18	28	33
Pick-Up Voltage	Max.	VDC	3	6	9	18	27
Drop-Out Voltage	Min.	VDC	1	1	1	1	1
Input Current at Rated Pick-Up Voltage	Max.	mA	10	10	10	10	13
Input Current at Max. Voltage	Max.	mA	25	25	25	20	20
Input Current (LED in Series with Nom. Voltage)	Typ.	mA	9	11	12	10	12
Input Resistance	Typ.	Ohms	270	680	1000	2200	2400

Voltage rise and fall rates of 1 v/ms or faster.

Output Specifications
(+25°C, unless otherwise specified)

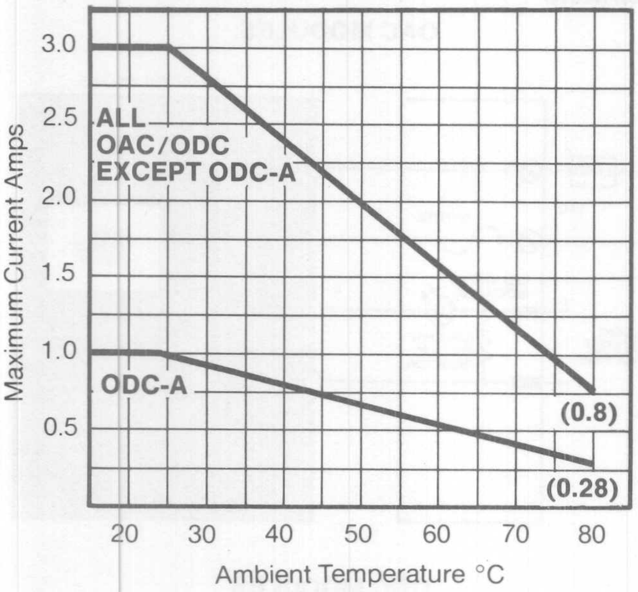
Parameter	Condition	Units	ODC5, ODC10, ODC15, ODC24, ODC30	ODC5A, ODC10A, ODC15A, ODC24A, ODC30A
Load Voltage	Range	VDC	5-60	5-200
Repetitive Blocking Voltage	Min.	VDC	60	200
Non-Repetitive Blocking Voltage	Min.	VDC	70	—
Load Current* (See Derating Curves)	Max. (I_1)	ADC	3	1
	Min. (I_2)	mADC	20	20
Current Derating Factor for Rise From +25°C to +80°C Ambient	@ I_1	A/°C	.040	.013
Non-Repetitive Surge Current for 1 Second	Max.	ADC	5	1.5
Off State Leakage Current	Max.	mADC	1.0 @ 60VDC	2.0 @ 200VDC
	Max. @ 32VDC	mADC	0.5	0.4
On State Voltage Drop	Typ. @ I_1	VDC	1.6	3.0
Turn On Time	Max.	μs	500	500
Turn Off Time	Max.	μs	500	500

†Models with "A" suffix are not UL/CSA.

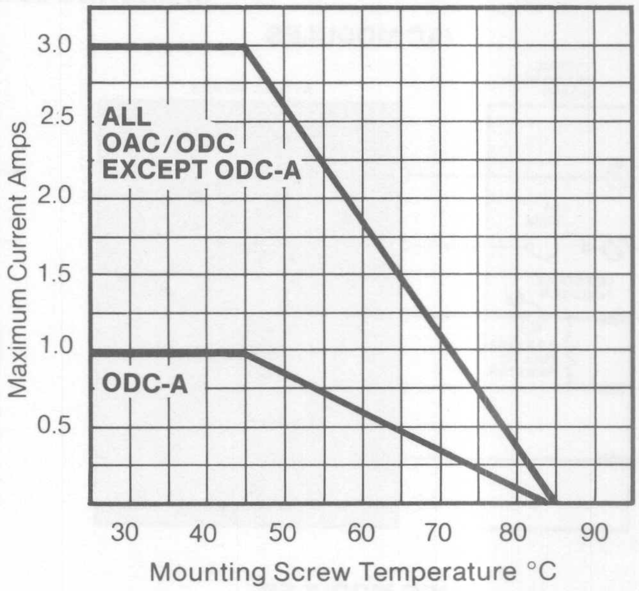
*Inductive loads should be diode suppressed.

OAC/ODC DERATING CURVES

Ambient Temperature vs Maximum Steady State rms Current Rating



Module Mounting Temperature vs Maximum Steady State Current Rating



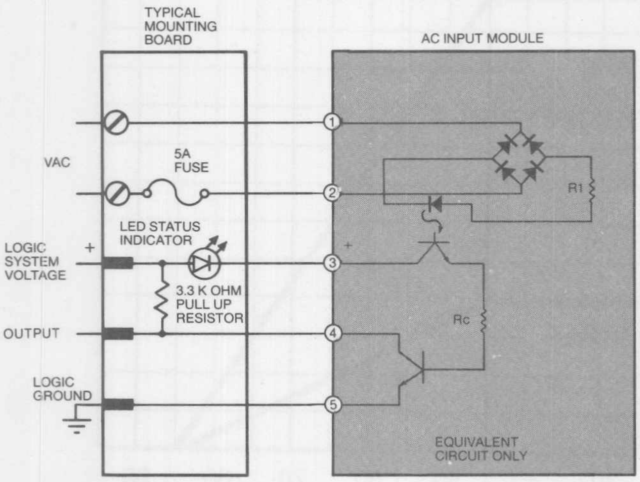
Ordering Information for Standard Models

Part Number	Type	Case Color	System Voltage	Max. Input Current at Max. Input Voltage	Max. Load Current at Max. Load Voltage
IAC5	AC Input	Yellow	5 VDC	12 mA @ 140 VAC	100 mA @ 30 VDC
IAC5A	AC Input	Yellow	5 VDC	8 mA @ 280 VAC	100 mA @ 30 VDC
IAC5E	AC Input	Yellow	5 VDC	24 mA @ 36 VAC	100 mA @ 30 VDC
OAC5	AC Output	Black	5 VDC	35 mA @ 6 VDC	3 A @ 140 VAC
OAC5A	AC Output	Black	5 VDC	35 mA @ 6 VDC	3 A @ 280 VAC
IDC5	DC Input	White	5 VDC	15 mA @ 32 VDC	100 mA @ 30 VDC
IDC5F	DC Input	White	5 VDC	15 mA @ 32 VDC	100 mA @ 30 VDC
ODC5	DC Output	Red	5 VDC	25 mA @ 6 VDC	3 A @ 60 VDC
ODC5A	DC Output	Red	5 VDC	25 mA @ 6 VDC	1 A @ 200 VDC
IAC10	AC Input	Yellow	10 VDC	12 mA @ 140 VAC	100 mA @ 30 VDC
IAC10A	AC Input	Yellow	10 VDC	8 mA @ 280 VAC	100 mA @ 30 VDC
IAC10E	AC Input	Yellow	10 VDC	24 mA @ 36 VAC	100 mA @ 30 VDC
OAC10	AC Output	Black	10 VDC	35 mA @ 13 VDC	3 A @ 140 VAC
OAC10A	AC Output	Black	10 VDC	35 mA @ 13 VDC	3 A @ 280 VAC
IDC10	DC Input	White	10 VDC	15 mA @ 32 VDC	100 mA @ 30 VDC
IDC10F	DC Input	White	10 VDC	15 mA @ 32 VDC	100 mA @ 30 VDC
ODC10	DC Output	Red	10 VDC	25 mA @ 13 VDC	3 A @ 60 VDC
ODC10A	DC Output	Red	10 VDC	25 mA @ 13 VDC	1 A @ 200 VDC
IAC15	AC Input	Yellow	15 VDC	12 mA @ 140 VAC	100 mA @ 30 VDC
IAC15A	AC Input	Yellow	15 VDC	8 mA @ 280 VAC	100 mA @ 30 VDC
IAC15E	AC Input	Yellow	15 VDC	24 mA @ 36 VAC	100 mA @ 30 VDC
OAC15	AC Output	Black	15 VDC	35 mA @ 18 VDC	3 A @ 140 VAC
OAC15A	AC Output	Black	15 VDC	35 mA @ 18 VDC	3 A @ 280 VAC
IDC15	DC Input	White	15 VDC	15 mA @ 32 VDC	100 mA @ 30 VDC
IDC15F	DC Input	White	15 VDC	15 mA @ 32 VDC	100 mA @ 30 VDC
ODC15	DC Output	Red	15 VDC	25 mA @ 18 VDC	3 A @ 60 VDC
ODC15A	DC Output	Red	15 VDC	25 mA @ 18 VDC	1 A @ 200 VDC
IAC24	AC Input	Yellow	24 VDC	12 mA @ 140 VAC	100 mA @ 30 VDC
IAC24A	AC Input	Yellow	24 VDC	8 mA @ 280 VAC	100 mA @ 30 VDC
IAC24E	AC Input	Yellow	24 VDC	24 mA @ 36 VAC	100 mA @ 30 VDC
OAC24	AC Output	Black	24 VDC	25 mA @ 28 VDC	3 A @ 140 VAC
OAC24A	AC Output	Black	24 VDC	25 mA @ 28 VDC	3 A @ 280 VAC
IDC24	DC Input	White	24 VDC	15 mA @ 32 VDC	100 mA @ 30 VDC
IDC24F	DC Input	White	24 VDC	15 mA @ 32 VDC	100 mA @ 30 VDC
ODC24	DC Output	Red	24 VDC	20 mA @ 28 VDC	3 A @ 60 VDC
ODC24A	DC Output	Red	24 VDC	20 mA @ 28 VDC	1 A @ 200 VDC
IAC30	AC Input	Yellow	30 VDC	12 mA @ 140 VAC	100 mA @ 30 VDC
IAC30A	AC Input	Yellow	30 VDC	8 mA @ 280 VAC	100 mA @ 30 VDC
IAC30E	AC Input	Yellow	30 VDC	24 mA @ 36 VAC	100 mA @ 30 VDC
OAC30	AC Output	Black	30 VDC	20 mA @ 33 VDC	3 A @ 140 VAC
OAC30A	AC Output	Black	30VDC	20 mA @ 33 VDC	3 A @ 280 VAC
IDC30	DC Input	White	30 VDC	15 mA @ 32 VDC	100 mA @ 30 VDC
IDC30F	DC Input	White	30 VDC	15 mA @ 32 VDC	100 mA @ 30 VDC
ODC30	DC Output	Red	30 VDC	20 mA @ 33 VDC	3 A @ 60 VDC
ODC30A	DC Output	Red	30 VDC	20 mA @ 33 VDC	1 A @ 200 VDC

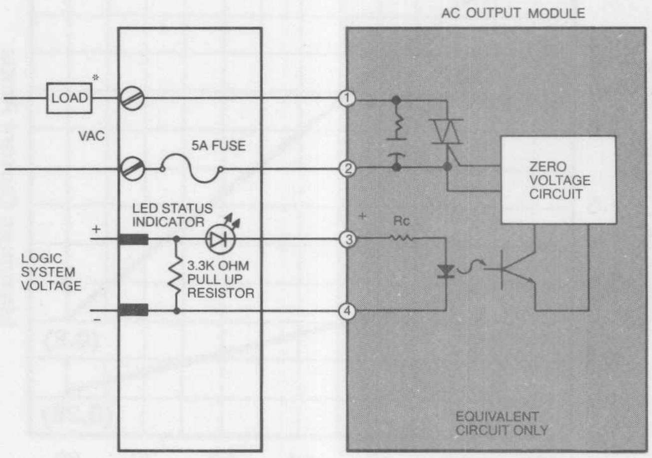
The models listed above are all potted units. Features such as metal oxide varistor or zener diode transient protection are available on Potter & Brumfield output models on a special order basis.

OPERATING DIAGRAMS

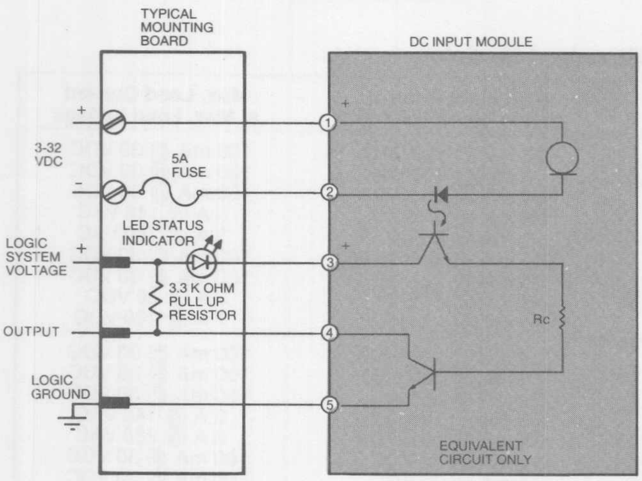
IAC MODULES



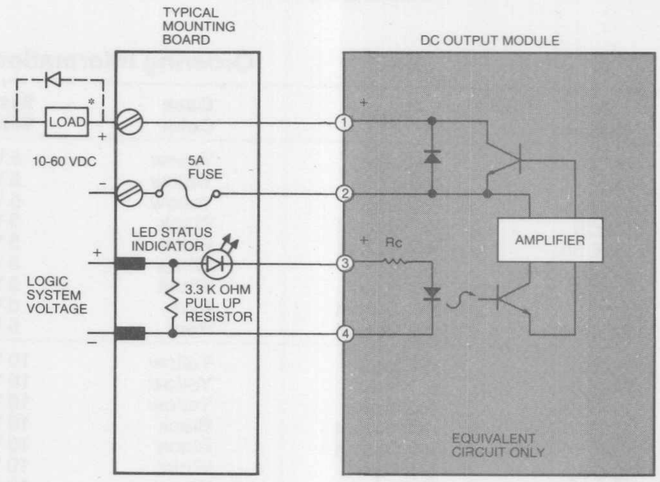
OAC MODULES



IDC MODULES

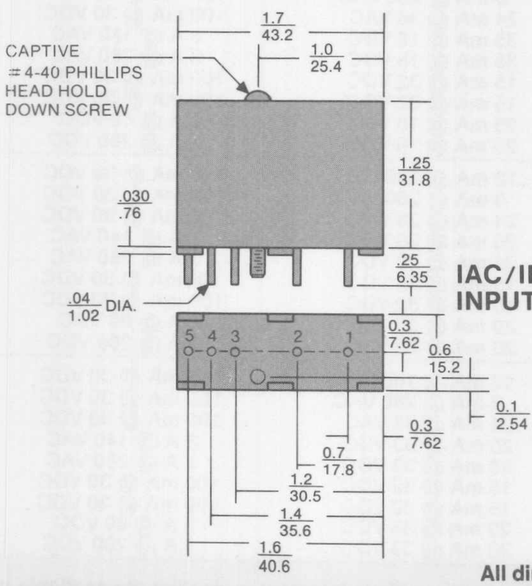


ODC MODULES

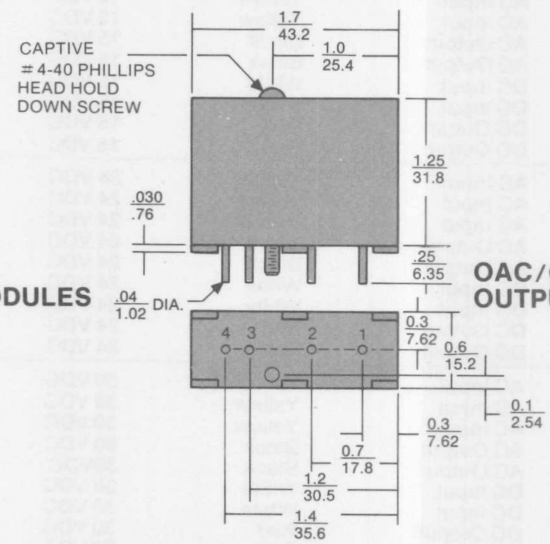


*Load can be placed in either side of the line.

OUTLINE DRAWINGS



IAC/IDC INPUT MODULES



OAC/ODC OUTPUT MODULES

All dimensions are given as $\frac{\text{inches}}{\text{mm}}$

2IO series

MOUNTING BOARDS FOR INPUT/OUTPUT MODULES

The 2IO series of mounting boards will accept as many as 4, 8, 16 or 24 input/output modules in any combination. Modules may be inserted and removed, quickly and easily, without disturbing field wiring. Once inserted, modules may be secured to the board by threading the captive hold-down screws into the nuts attached to the board.

An LED status indicator, plug-in 5 amp fuse, and 3.3K ohm pull-up resistor are provided on the mounting board for each module. Each module position may be color coded for convenience in maintaining and servicing the system.

Screw terminals in barrier strips are used for logic supply input connections and field input/output connections on all mounting boards. The four-position board (2IO-4A) and one of the 16-position boards (2IO-16A) also have screw terminals in a barrier strip for connection to the logic system. Screw terminals on all mounting boards will accept two #12 gauge wires.

Mounting boards with 8, 16 and 24 positions (2IO-8, 2IO-16 and 2IO-24) have card edge patterns which accept standard 50 pin cable connectors for logic connections. Eight position mounting board (2IO-8) will also accept a 26 pin cable connector. Each module position on these boards is served by two of the cable's conductors. Odd-numbered pins are used for signals while even-numbered pins are connected to logic ground. Jumper locations permit logic supply input to be introduced through the cable, rather than the screw terminals.

FEATURES

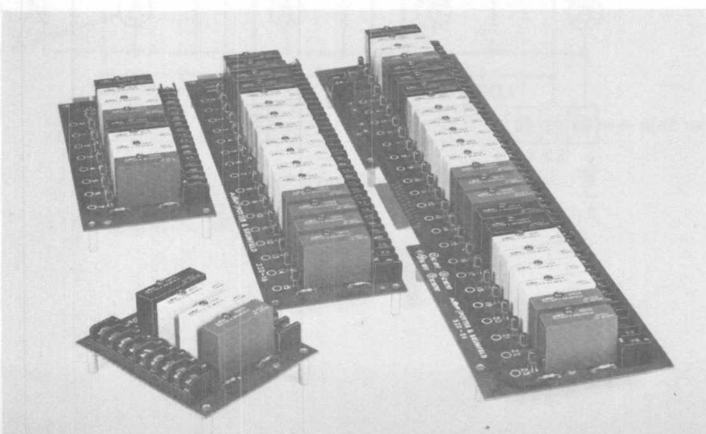
- LED Status Indicators
- Plug-in Fuses
- Pull-up Resistors
- Card Edge Logic Connections (2IO-8, 2IO-16 and 2IO-24)
- Screw Terminal Logic Connections (2IO-4A & 2IO-16A)
- Screw Terminals for Field Wiring
- UL File E61482
- CSA File LR15734

Mounting Board Comparison Chart

Interface Connector Types, Fuse Types and Agency Recognitions

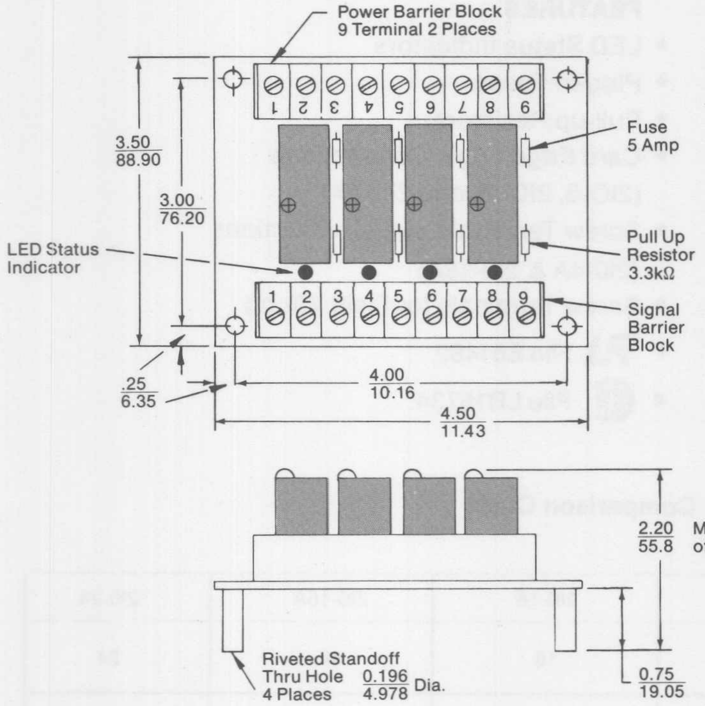
Part Number	2IO-4A	2IO-8	2IO-16	2IO-16A	2IO-24
Number of Module Positions	4	8	16	16	24
Notes	1 4 6 7	2 3 4 6 7	3 4 6 7	1 4 6 7	3 4 5 6 7
1	Barrier Terminal Strip				
2	26-pin Card Edge Connector*: T&B Ansley P/N 609-2615M; 3M P/N 3462-0001				
3	50-pin Card Edge Connector:* T&B Ansley P/N 609-5015M; 3M P/N 3415-0001				
4	5 Amp Fuse: Littlefuse P/N 275-005; Bussmann P/N GFA5				
5	1 Amp Fuse: Littlefuse P/N 275-001; Bussmann P/N GFA1				
6	UL Recognized / CSA Certified for 125V Max. with 5 amp fuses				
7	UL Recognized / CSA Certified for 250V Max. with #22 solid copper jumper wire instead of 5 amp fuses				

*Logic interface connector contacts are spaced on 0.1″ centers.



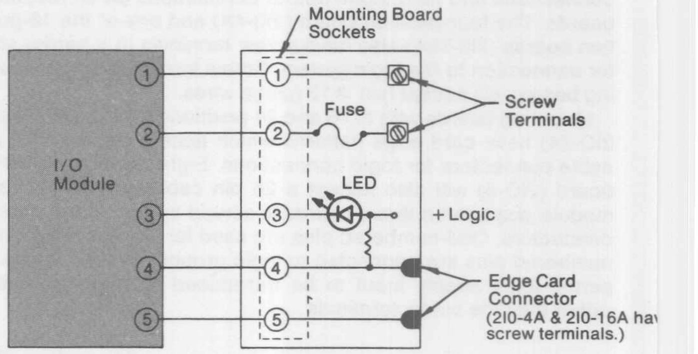
2IO-4A MOUNTING BOARD

Outline Drawing

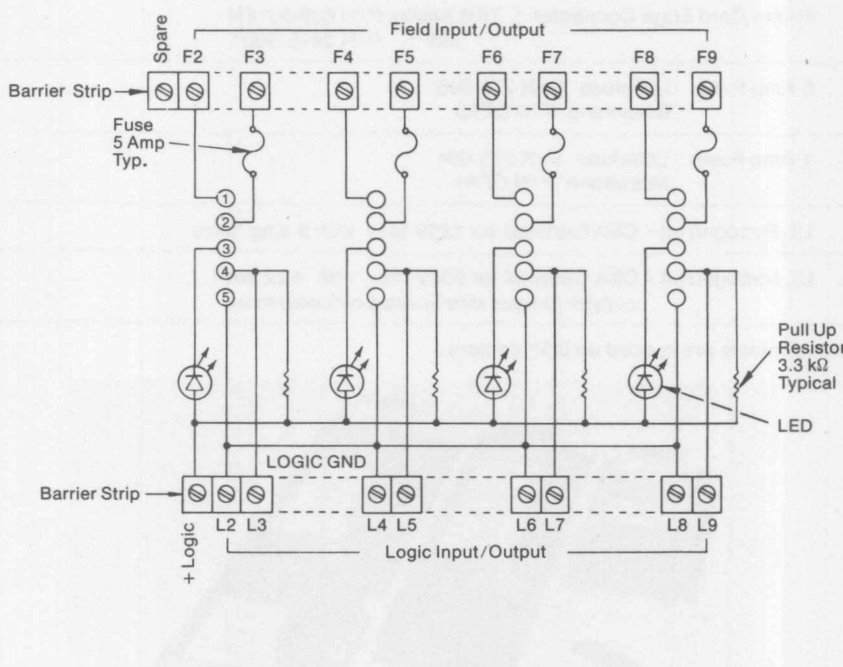


All dimensions are given as $\frac{\text{inches}}{\text{mm}}$

Mounting Board System

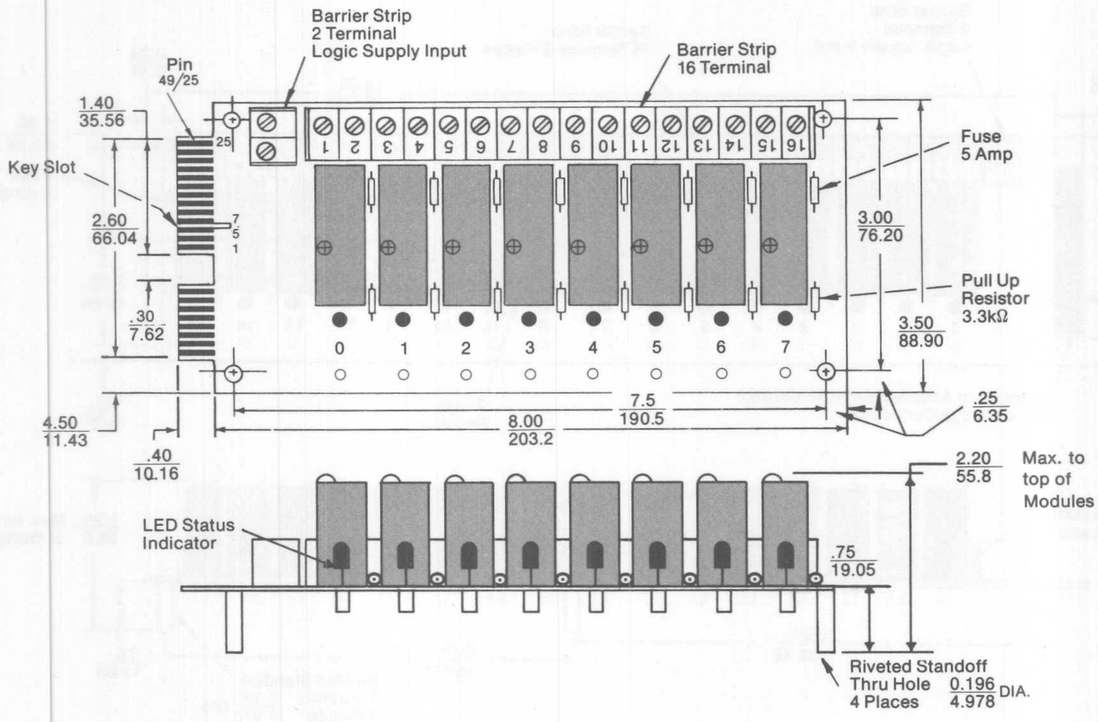


Schematic



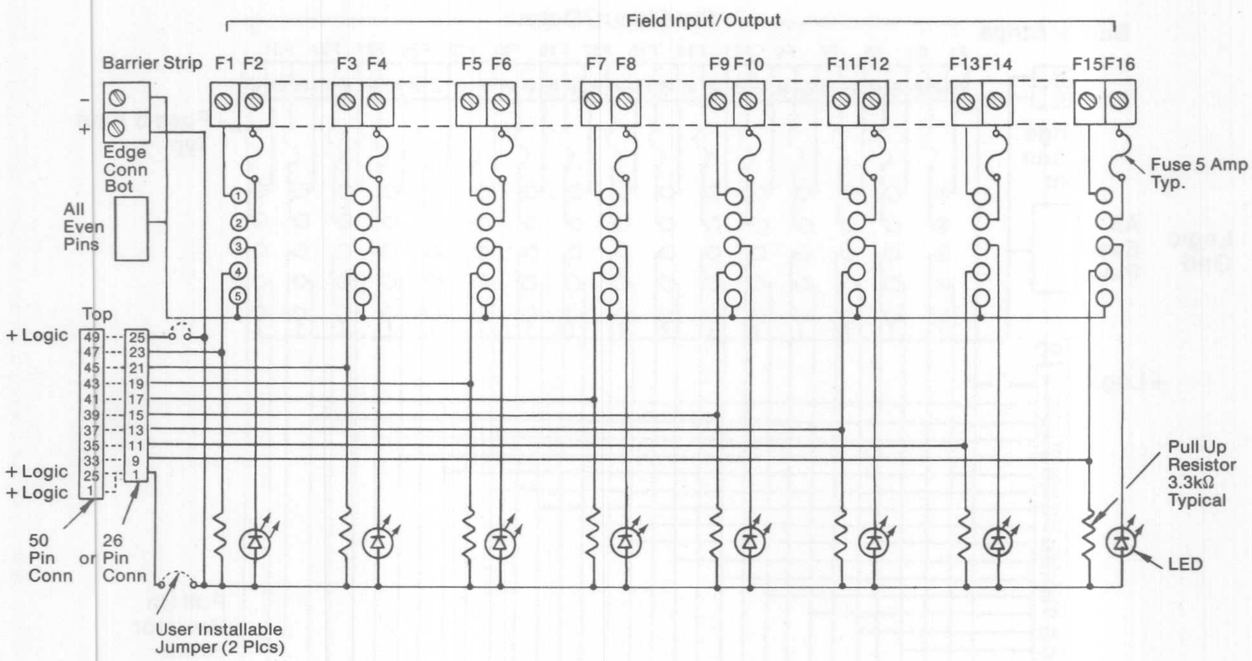
2IO-8 MOUNTING BOARD

Outline Drawing



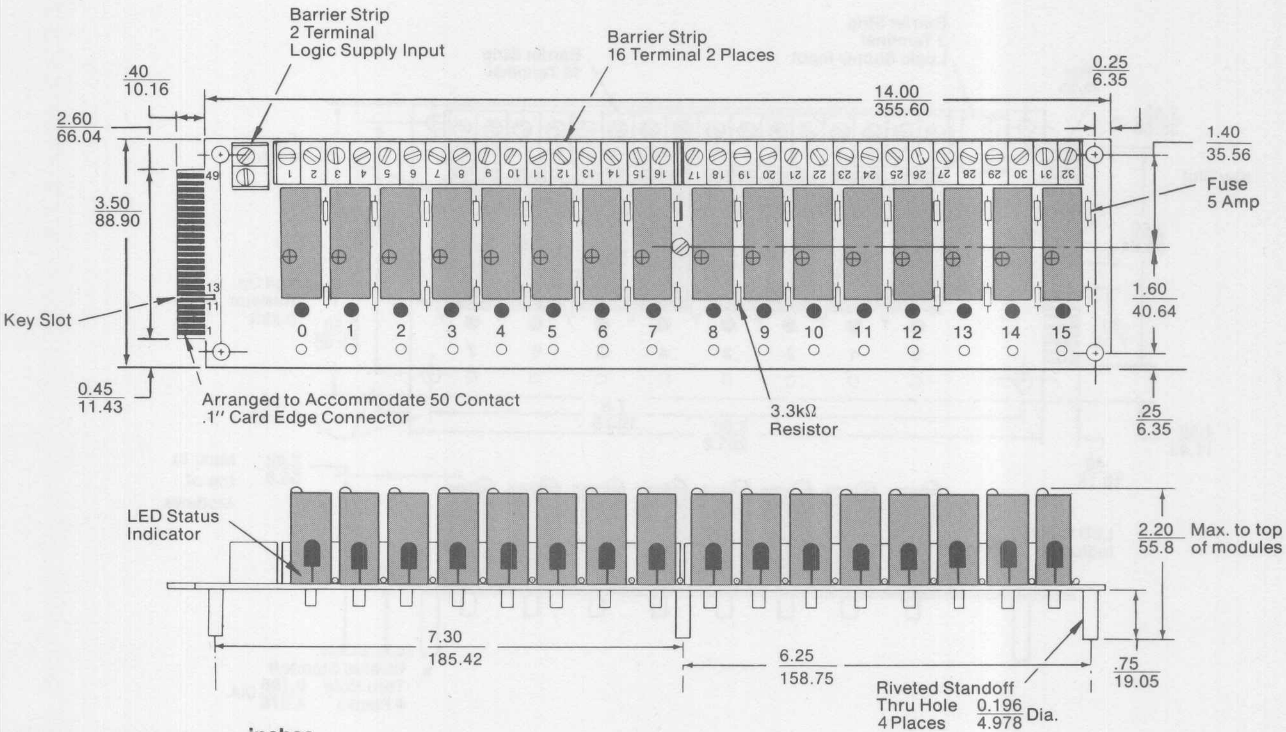
All dimensions are given as $\frac{\text{inches}}{\text{mm}}$

Schematic



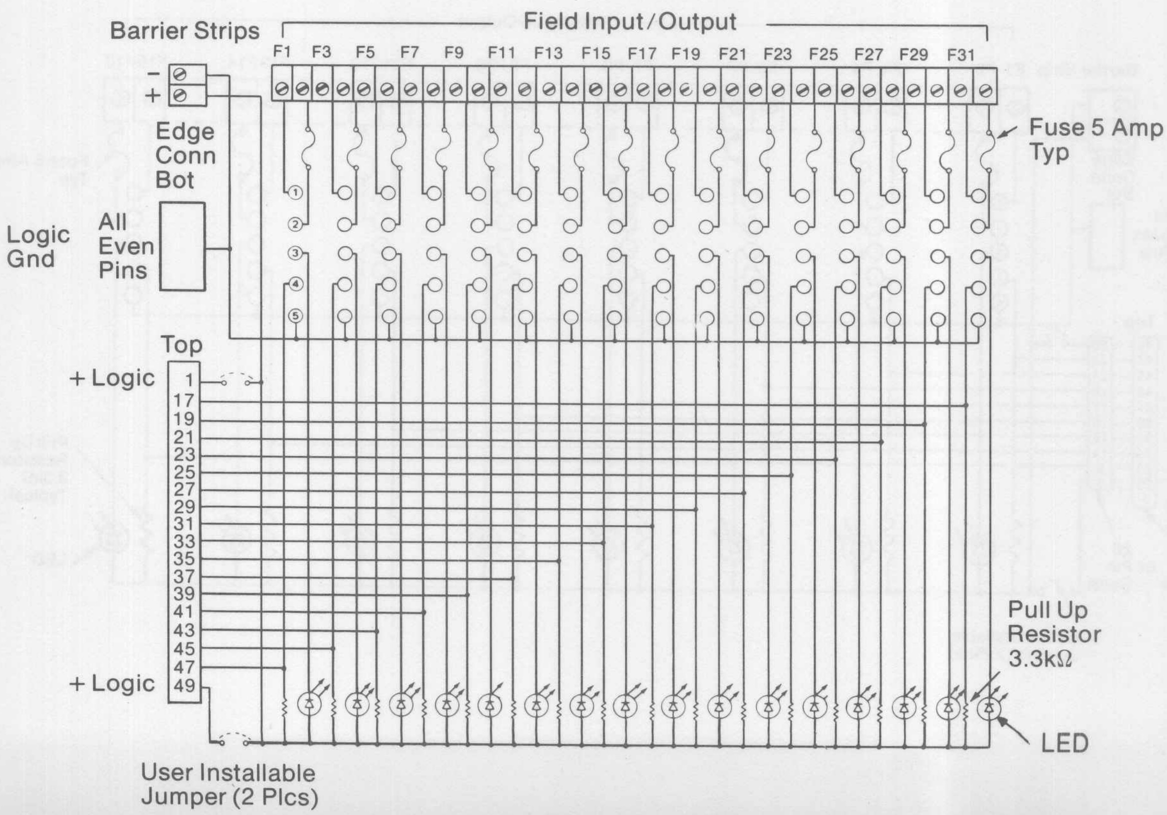
2IO-16 MOUNTING BOARD

Outline Drawing



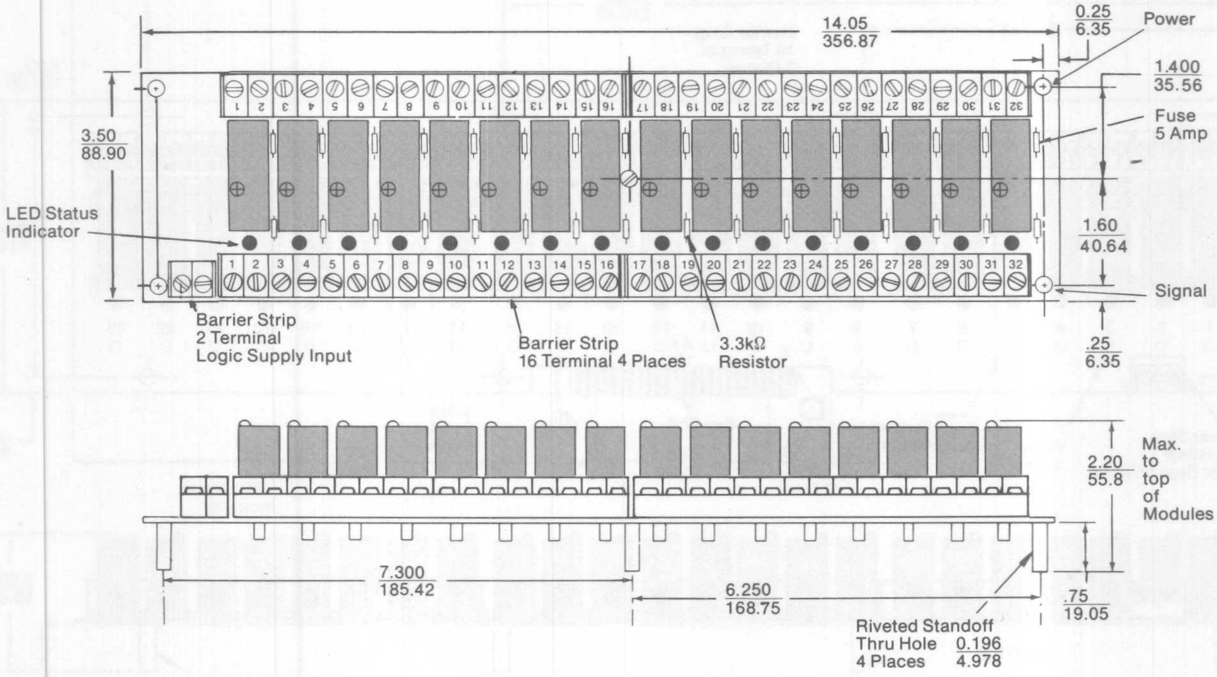
All dimensions are given as $\frac{\text{inches}}{\text{mm}}$

Schematic



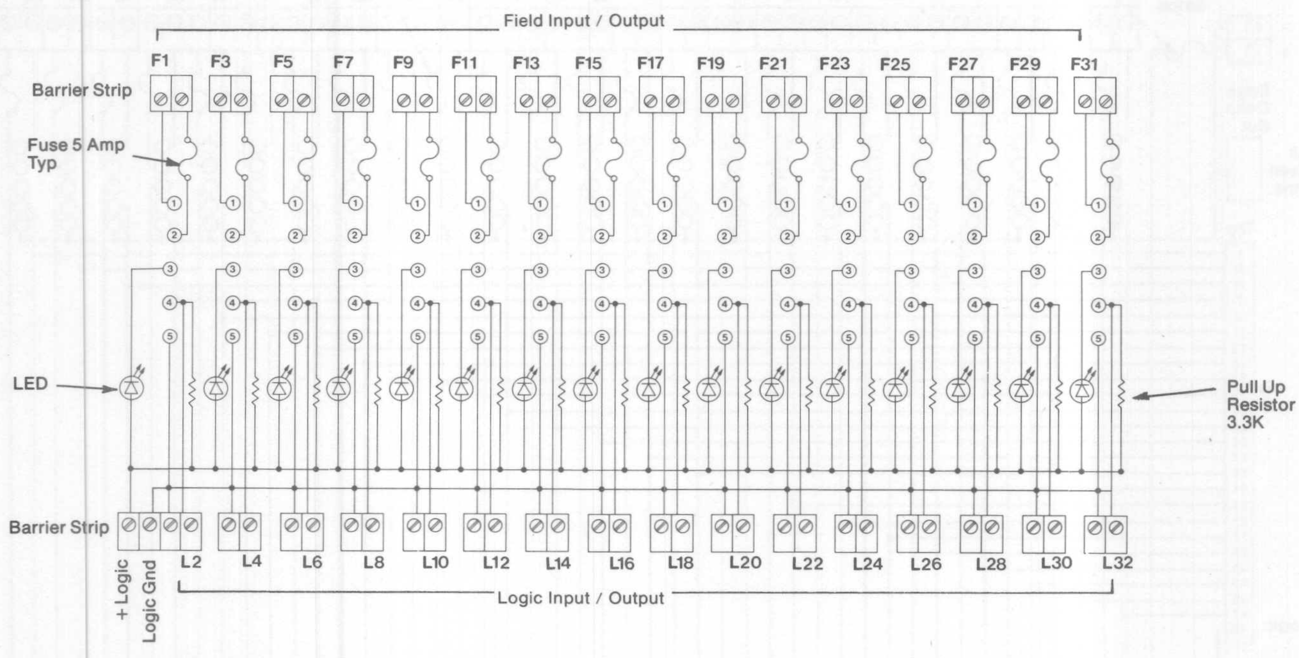
2IO-16A MOUNTING BOARD

Outline Drawing



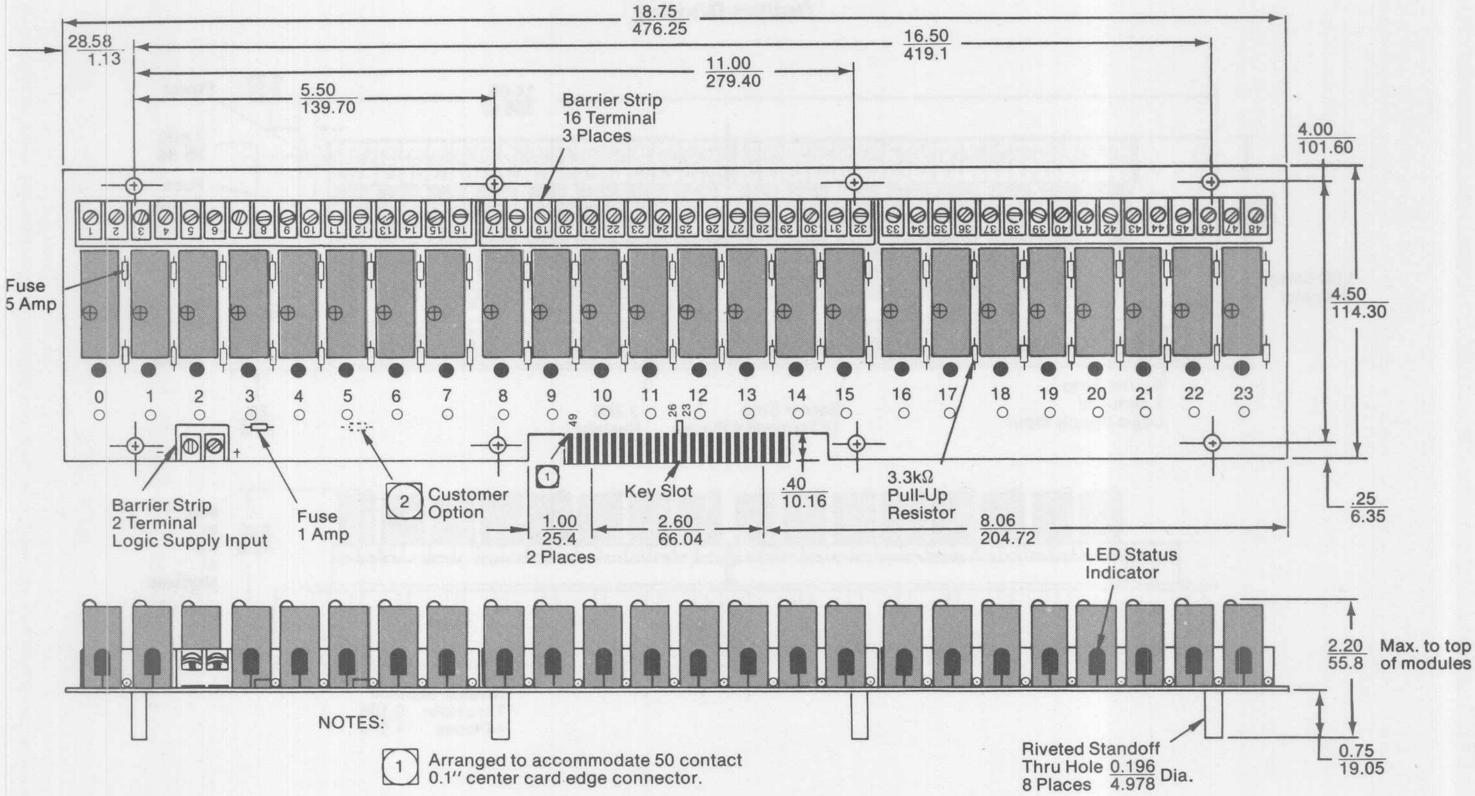
All dimensions are given as $\frac{\text{inches}}{\text{mm}}$

Schematic



2IO-24 MOUNTING BOARD

Outline Drawing

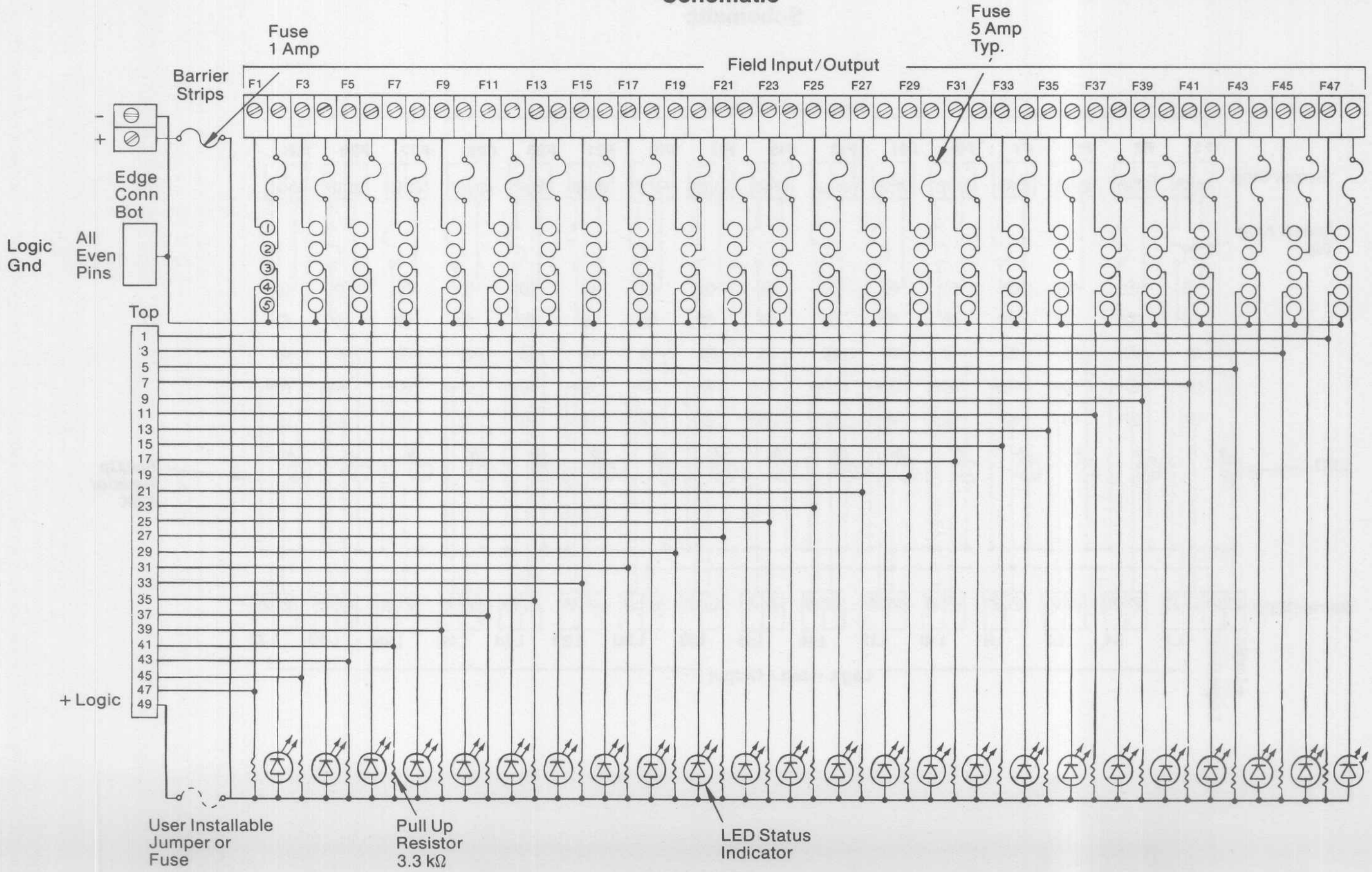


NOTES:

1. Arranged to accommodate 50 contact 0.1'' center card edge connector.
2. + Logic available at Pin 49 by relocating fuse.

All dimensions are given as inches / mm

Schematic



STOCK ITEMS

The following part numbers are included in Potter & Brumfield's distributor stock program. Therefore, they are much more likely to be in stock than are other part numbers which may be obtained using the ordering information charts for the various products. Part numbers which are not in stock are subject to standard OEM leadtimes.

HYBRID RELAYS

TYPE	INPUT Volts	OUTPUT VAC Range	OUTPUT Max. Amps	See Page
•ECM1DE72	5 DC 12 DC 24 DC	24-140	25	23
•*ECT1AC22	120 AC	24-140	3.5	27
•*ECT1AC42	120 AC	24-140	10	27
•*ECT1AC72	120 AC	24-140	25	27
•*ECT1AC74	120 AC	24-280	25	27
•*ECT1DB44	24 DC	24-280	10	27
•*ECT1DC22	5 DC 12 DC 24 DC	24-140	3.5	27
•*ECT1DC42	12 DC 24 DC	24-140	10	27
•*ECT1DC52	5 DC	24-140	15	27
•*ECT1DC72	5 DC 12 DC 24 DC	24-140	25	27
•*ECT1DC74	5 DC 12 DC 24 DC	24-280	25	27

SOLID STATE RELAYS

TYPE	INPUT DC Volts	OUTPUT VAC Range	OUTPUT Max. Amps	See Page
•EOM1DA22	3-32 5 12 24	24-140	3.5	31
•EOM1DA24	3-32 5 12 24	24-280	3.5	31
•EOM1DA42	3-32 5 12 24	24-140	10	31
•EOM1DA44	3-32 5 12 24	24-280	10	31
•EOM1DA54	3-32 5 12 24	24-280	15	31
•EOM1DA72	3-32 5 12 24	24-140	25	31
•EOM1DA74	3-32 5 12 24	24-280	25	31

SOLID STATE RELAYS

TYPE	INPUT DC Volts	OUTPUT VAC Range	OUTPUT Max. Amps	See Page
•EOT1DB22	3-32	24-140	3.5	35
•EOT1DB42	3-32	24-140	10	35
•EOT1DB52	3-32	24-140	15	35
•EOT1DB72	3-32	24-140	25	35
•EOT1DC22	3-32 5	24-140	3.5	35
•EOT1DC42	5	24-140	10	35
•EOT1DC72	3-32 5	24-140	25	35
•EOT1DC74	3-32 5	24-280	25	35
ETC-1000	18-32	24-140	25	39
ETC-1100	18-32	24-140	25	39

INPUT/OUTPUT MODULES

TYPE	Usage	DC Logic Volts	Nom. Input Volts	Max. Load Amps at Max. Load Volts	See Page
•*IAC5 •*IAC5A IAC5E •*IAC15 •*IAC15A IAC15E •*IAC24 •*IAC24A IAC24E	AC Input	5 5 5 15 15 15 24 24 24	120AC 240AC 24AC 120AC 240AC 24AC 120AC 240AC 24AC	.1@30DC .1@30DC .1@30DC .1@30DC .1@30DC .1@30DC .1@30DC .1@30DC .1@30DC	42
•*IDC5 IDC5F •*IDC15 IDC15F •*IDC24 IDC24F	DC Input	5 5 15 15 24 24	3-32DC 3-32DC 3-32DC 3-32DC 3-32DC 3-32DC	.1@30DC .1@30DC .1@30DC .1@30DC .1@30DC .1@30DC	42
•*OAC5 •*OAC5A •*OAC15 •*OAC15A •*OAC24 •*OAC24A	AC Output	5 5 15 15 24 24	5DC 5DC 15DC 15DC 24DC 24DC	3@140AC 3@280AC 3@140AC 3@280AC 3@140AC 3@280AC	42
•*ODC5 •*ODC15 •*ODC24	DC Output	5 15 24	5DC 15DC 24DC	3@60DC 3@60DC 3@60DC	42

MOUNTING BOARDS

TYPE	Number of Module Positions	Approximate Dimensions in inches (L x W x H†)	See Page
•*2IO-4A	4	4.5 x 3.5 x 2.2	49
•*2IO-8	8	8.4 x 3.5 x 2.2	49
•*2IO-16	16	14.4 x 3.5 x 2.2	49
•*2IO-16A	16	14.05 x 3.5 x 2.2	49
•*2IO-24	24	18.75 x 4.5 x 2.2	49

†Height is measured to top of mounted modules.

•UL recognized component.
*CSA certified component.

GLOSSARY

Bounce—Contact bounce is the damped rebounding of the movable after first striking the stationary upon make of the contacts, or upon remake after the contacts have opened due to shock, vibration, or acceleration.

Breakover Turn-On—Turn-on of an SSR in the absence of input control due to a voltage across the output in excess of the forward breakover voltage.

Buffer—An isolating circuit used to avoid reaction of a driven circuit upon the corresponding driving circuit.

Commutating-Off—The characteristic of a thyristor to revert to the off-state when load current falls below the minimum on-state holding current.

Commutation—The transfer of AC load current from one thyristor (or triac operating state) to another as the current passes through zero on the AC cycle.

Control Voltage and/or Current, Nominal—The normal control voltage and/or current intended to be applied to the input of an SSR.

Control Voltage and/or Current, Maximum—The maximum control voltage and/or current intended to be applied to the input of an SSR.

Current, AC Leakage—The effective current that flows in the load circuit when an SSR is in the off-state.

Current, Inrush—The current flowing in a load circuit immediately following turn-on. For capacitive, transformer, motor and tungsten lamp loads the level of the inrush usually will exceed the steady state current for some period of time following turn-on.

Current, Load—The current that flows in the load circuit when an SSR is on.

Current, Nonrepetitive Surge, Peak, Maximum—The maximum nonrepetitive peak surge current that may be conducted by an SSR for a specific duration. Relay control may be lost during and following the surge due to excessive heating. Stresses incurred have a cumulative effect.

Current, On-State Holding, Minimum—The minimum current required to maintain an SSR in the on-state.

Current, Repetitive Surge, Peak Maximum—The maximum repetitive peak surge current that may be conducted by an SSR for a specific duration and duty cycle while still maintaining output control.

Current, Steady State rms, Maximum—The maximum effective steady state current conducted by an SSR.

Dielectric Strength—The maximum allowable AC rms voltage which may be applied between input and output, input to case and output to case.

di/dt, Breakover Voltage Turn-On, Maximum—The maximum nonrepetitive rate of rise of load current when an SSR is turned on by a voltage breakover. Higher di/dt may damage the relay.

di/dt, Input Controlled Turn-On, Maximum—The maximum nonrepetitive rate of rise of load current when an SSR is turned on by the control input. Higher di/dt may damage the relay.

Duty Cycle—A statement of on-time and off-time in a repetitious operation, for example, 2 seconds on, 6 seconds off, 2 seconds on, etc.

dv/dt, Commutating, Maximum—The maximum rate of rise of reapplied AC line voltage to the off-state output immediately following a zero current turn-off. Higher commutating dv/dt may prevent input controlled turn-off of the SSR.

dv/dt, Off-State, Maximum—The maximum rate of rise of off-state voltage to be applied to the output. Higher dv/dt may result in turn-on of the SSR.

Electromechanical Relay (EMR)—A relay that mechanically opens or closes metallic electrical contacts by utilizing an electrical input to create a motive force to perform the mechanics of moving the contacts. (The most common type electromechanical relay is the electromagnetic and is the one usually thought of when reference to an EMR device is made.) (NARM)

Electromagnetic Interference (EMI)—The impairment of a desired electromagnetic signal by a superimposed electromagnetic disturbance or phenomenon.

Half Cycling—A false turn-on of the off-state SSR for a portion of one half cycle. It is usually caused by load circuit voltage transients appearing across the output that exceed off-state dv/dt and/or breakover voltage capabilities of the relay.

Hybrid Electromechanical Relay (HEMR)—A relay with isolated input and output in which electromechanical and electronic devices are combined to perform a switching function with an electromechanical output. Switching characteristics are dictated by electromechanical relay specifications. (NARM)

Hybrid Solid State Relay (HSSR)—A relay with isolated input and output in which electromechanical and electronic devices are combined to perform a switching function with a solid state output. (NARM)

Hysteresis—The difference between the "must operate" and "must release" control voltages.

Input—That portion of an SSR/HSSR to which a control signal is applied in order to achieve the switching function.

Isolation—The value of insulation resistance, dielectric strength, and capacitance measured between the input and output, input to case, and output to case.

Light Emitting Diode (LED)—A semiconductor device from which light is produced when a forward current flows as a result of applied voltage.

Must Not Operate Voltage and/or Current—The maximum control voltage which can be applied to the relay input and have it remain in the nonoperate state.

Must Operate Voltage and/or Current—The specified control voltage and/or current level at which the output will change state.

Must Release Voltage and/or Current—The specified applied control voltage and/or current level which will allow the relay, once operated, to change state.

Operate Time—The time lapse between the application of a step "must operate" voltage and/or current and the change of state at the output when switching at rated voltage, current, and line frequency. (NARM)

Opto-Coupled SSR—An SSR where isolation between input and output is provided by light transmission within an opto-coupler. These relays usually incorporate zero voltage turn-on.

Output—That portion of an SSR which performs the switching function required.

p-n Junction—A region of transitions between p-type and n-type semiconducting material.

Power Dissipation—The average power dissipation at a given load current.

Radio Frequency Interference (RFI)—Electromagnetic interference in the radio frequency range.

Random Turn-On—Initial turn-on may occur at any point on the AC line voltage cycle except at or very near zero voltage.

GLOSSARY

Reed Relay Coupled HSSR—An HSSR where isolation between input and output is provided by the magnetic circuit of the reed relay. These relays are usually random turn-on devices.

Release Time—The time lapse between the application of a step transition from the maximum allowable voltage and/or current to the must release voltage and/or current and a change in state of the output when switching rated voltage, current and line frequency. (NARM)

Resistance, Insulation—The minimum allowable DC resistance between input and output, input to case, and output to case.

Resistance, Thermal—Temperature rise per unit power dissipation above the temperature of a reference point under condition of thermal equilibrium, in degrees Celsius per watt (°C/W).

Silicon Controlled Rectifier (SCR)—A reverse blocking triode thyristor.

Snubber Network (dv/dt Network)—Typically a series RC network that is placed across the output of an SSR. It reduces the dv/dt of load circuit transients and reapplied line voltage during commutation thereby reducing susceptibility to false turn-on and loss of control.

Solid State Relay (SSR)—A relay with isolated input and output whose functions are achieved by means of electronic components and without the use of moving parts. (NARM)

Thyristor—A bistable semiconductor device that can be switched from the off-state to the on-state or vice versa.

Transformer Coupled SSR—An SSR where isolation between input and output is provided by the transformer in the transformer coupler.

Transient—A temporary current or voltage excursion that occurs in a circuit because of a sudden change of voltage or load.

Triac—A bidirectional triode thyristor used for switching AC current.

Voltage, Breakover—The voltage across the output of an SSR in the off-state at which a breakover turn-on occurs.

Voltage, On-State—The voltage drop through the output of an SSR in the on-state.

Voltage, Nonrepetitive Peak Blocking, Maximum—The maximum voltage to be applied to the output of an SSR in the off-state. Higher voltages may result in breakover turn-on.

Voltage, Repetitive Peak Blocking, Maximum—The maximum peak steady state voltage to be applied to the output of an SSR in the off-state.

Zero Current Turn-Off—Turn-off at essentially the zero crossing of the load current that flows through an SSR. A thyristor will turn off only when the current falls below the minimum holding current. If input control is removed when the current is a higher value, turn-off will be delayed until the next zero current crossing.

Zero Voltage Turn-On—Initial turn-on occurs at a point near zero crossing of the AC line voltage. If input control is applied when the line voltage is at a higher value, initial turn-on will be delayed until the next zero crossing.

1 Form A—A single pole single throw normally open switch.

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